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GEM-GLO Content and References

GEM-GHG Emissions Monitoring – Domain Gobal

Version GCCIv1.2 Information Sheet on the GEM-GLO Variables Tabular List of Variables & SubVariables together with explanations and data source references

How-to-Read Template: Format and content of the information per Variable in the Table below

VN. Variable N	Explanation: brief explanation of what Variable N expresses and optionally (e.g., in case of an index variable in units [%]) how it is computed		
[Unit]	<datasourceshortcite string="" vn=""> (as cited within the chart at the GCCI data portal)</datasourceshortcite>		
	SVN.1 SubVariable <i>N</i> .1 Name	<datesources string="" svn.1=""> (from GCCIv1 SV definitions file)</datesources>	
		Reference(s) to the data source(s) for SVN.1, incl DOIs, Weblinks, etc, as available (one or more detailed references)	
	SVN.2 SubVariable <i>N</i> .2 Name	<datesources string="" svn.2=""> (from GCCIv1 SV definitions file)</datesources>	
		Reference(s) to the data source(s) for SVN.2, incl DOIs, Weblinks, etc, as available (one or more detailed references)	
	SVN.3	<datesources string="" svn.3=""> (from GCCIv1 SV definitions file)</datesources>	
	Name	Reference(s) to the data source(s) for SVN.3, incl DOIs, Weblinks, etc, as available (one or more detailed references)	
	SVN.4	<datesources string="" svn.4=""> (from GCCIv1 SV definitions file)</datesources>	
	Name	Reference(s) to the data source(s) for SVN.4, incl DOIs, Weblinks, etc, as available (one or more detailed references)	

GEM-GLO Information Sheet Table: GEM-GHG Emissions Monitoring – Domain Global

Variable (V) Name	SubVariable (SV) Name	Variable Explanation and Data Source References
V1. CO2-based climate change (CC) mitigation index [%]	Explanation:This is one of the two primary index variables of GEM-GLO, on annual CO2 emissions of countries, relevant country groups, and glob It indicates the success of emission reductions in any given year as a peri the annual-average 1990-1994 CO2 emissions ("Em(Year i)" vs "AvgEm(1)" The SubVariables include the main GCCI climate change mitigation index as well as the production-based (SVs 1.3&1.5) and consumption-based (S emission reduction indices, respectively, either up to the latest year with or also including a reduction scenario to 2050 compliant with the Paris c ("incl path2Paris" SVs). The scenarios are modeled for GCCIv1 according "linear reduction & residual floor emission path model" of Kirchengast (2 Williges et al. (2021) (except for SVs 1.2&1.5 for Austria as explained in G model provides 2017-2050 paths consistent with the CO2 budget allocate or country group on an equal-per-person basis from a remaining 2017-20 budget of 700 GtCO2 with a residual-floor annual global emission of 3.5 G Formula for the GCCI climate change mitigation index gauging emission (based on the production-based emission data) Index(Year i) [%] = 100 x [Em(Year i)/AvgEm(1990-1994) - 1] Formula for the production- and consumption-based emission reduction index (Year i) [%] = 100 x [Em(Year i)/AvgEm(1990-1994)]The main GCCI index hence expresses the level of reductions against 0% indicates success for achieving percentage values below 0% towards -10 neutrality) while it indicates failure by values that stick above 0% or even The complementary two indices rather gauge the changes against 100%	
SV1.1 GCCI CC mitigation index CO2 emission reduction (goal -100%	 WEGC-GCCI/Kirc-etal 2021 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-GLO. DocID GCCIv1.2-GEM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/gem</u> (see under "Explanation" above on the index computation) 	
	94=0%)	
	GCCI CC mitigation index CO2 emission reduction incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-GLO. DocID GCCIv1.2-GEM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/gem Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
SV1.3 Production- based CO2 emission	 WEGC-GCCI/Kirc-etal 2021 & GCP-GloCarbProj 2020 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-GLO_DocID GCCIv(12-GEM-GLO-Apr2022) Wegener Center 	

redu index SV1 Cons -base emis redu index SV1 Prod base emis redu index SV1 Cons -base emis redu index path SV1 SV1 Cons -base emis redu index path SV1 SV1 End base emis redu index path SV1 SV1 End SV1 End SV1 End SV1 End End End End End<	reduction index	 Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/gem</u> (see under "Explanation" above on the index computation) Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at <u>https://doi.org/10.5194/essd-12-3269-2020</u>
	SV1.4 Consumption -based CO2 emission reduction index	 WEGC-GCCI/Kirc-etal 2021 & GCP-GloCarbProj 2020 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-GLO. DocID GCCIv1.2-GEM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/gem (see under "Explanation" above on the index computation) Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at https://doi.org/10.5194/essd-12-3269-2020
	SV1.5 Production- based CO2 emission reduction index incl path2Paris	 WEGC-GCCI/Kirc-etal 2021 (incl GCCIv1 EPClin&floor-scen) Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-GLO. DocID GCCIv1.2-GEM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/gem Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
	SV1.6 Consumption -based CO2 emission reduction index incl path2Paris	 WEGC-GCCI/Kirc-etal 2021 (incl GCCIv1 EPClin&floor-scen) Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-GLO. DocID GCCIv1.2-GEM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/gem Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
V2. GHG-based climate change (CC) mitigation index [%]	 Explanation: See the explanation at the beginning of the Variable V1 block above SubVariables of this Variable V2 are constructed in exactly the same way but bas the annual greenhouse gas (GHG) emissions of countries, relevant country group globally since 1990 rather than on CO₂ emissions only. The GHG emissions include all climate-relevant GHGs according to international accounting principles (also CH₄, N₂O, etc.) and are measured in Million tons of CC equivalent [MtCO₂eq] (see under Variable V4 below). The scenarios to 2050 are i case based on a remaining 2017-2050 global GHG budget of 1000 GtCO₂eq with a residual-floor annual global emission of 5 GtCO₂eq/yr. 	
	WEGC-GCCI 202	21 & UN&GCP EmDBs 2020
	SV2.1 GCCI CC mitigation index GHG emission	 WEGC-GCCI/Kirc-etal 2021 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-GLO. DocID GCCIv1.2-GEM-GLO-Apr2022, Wegener Center,

reduction (goal -100% vs 1990- 94=0%)	Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/gem</u> (see under "Explanation" above on the index computation)
SV2.2 GCCI CC mitigation index GHG emission reduction incl path2Paris	 WEGC-GCCI/Kirc-etal 2021 (incl GCCIv1 EPClin&floor-scen) Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-GLO. DocID GCCIv1.2-GEM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/gem Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
SV2.3 Production- based GHG emission reduction index	 WEGC-GCCI/Kirc-etal 2021 & UN-EmissionsDB 2020 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-GLO. DocID GCCIv1.2-GEM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/gem (see under "Explanation" above on the index computation) United Nations Framework Convention on Climate Change (UNFCCC) (2020). Greenhouse Gas Inventory Data. Online at https://di.unfccc.int/time_series
SV2.4 Consumption -based GHG emission reduction index	 WEGC-GCCI/Kirc-etal 2021 & UN&GCP EmissionsDBs 2020 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-GLO. DocID GCCIv1.2-GEM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/gem (see under "Explanation" above on the index computation) United Nations Framework Convention on Climate Change (UNFCCC) (2020). Greenhouse Gas Inventory Data. Online at https://di.unfccc.int/time_series Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at https://doi.org/10.5194/essd-12-3269-2020
SV2.5 Production- based GHG emissions incl path2Paris	 WEGC-GCCI/Kirc-etal 2021 (incl GCCIv1 EPClin&floor-scen) Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-GLO. DocID GCCIv1.2-GEM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/gem Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request) WEGC-GCCI/Kirc-etal 2021 (incl GCCIv1 EPClin&floor-scen)
SV2.0 Consumption -based GHG emissions	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet

	incl path2Paris	<i>GEM-GLO</i> . DocID GCCIv1.2-GEM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/gem</u>
		 Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
V3. CO2 annual emissions [MtCO ₂]	Explanation: The the one based of globally since 19 The SubVariable 3.2&3.4) annua latest year with with the Paris of The scenarios a floor emission p for SV3.3 for Au consistent with person basis from	his is one of the two primary amount-of-emissions variables of GEM-GLO, on annual CO ₂ emissions of countries, relevant country groups, and 290 (except production-based CO ₂ emissions being available from 1960). es include production-based (SVs 3.1&3.3) and consumption-based (SVs I emissions measured in Million tons of CO ₂ [MtCO ₂], either up to the data (first SVs) or also including a reduction scenario to 2050 compliant limate goals ("incl path2Paris" SVs). re modeled for GCClv1 according to a simple "linear reduction & residual bath model" of Kirchengast (2021) following Williges et al. (2021) (except stria as explained in GEM-AT). This model provides 2017-2050 paths the CO ₂ budget allocated to a country or country group on an equal-per- om a remaining 2017-2050 global CO ₂ budget of 700 GtCO ₂ with a
	residual-floor a	nnual global emission of 3.5 GtCO ₂ /yr.
	GCP-Global Carl	bon Project 2020 & WEGC 2021
	SV3.1 Production- based CO2 emissions	 GCP-Global Carbon Project 2020 / WEGCupd 2021 Friedlingstein et al. (2020). <i>Global Carbon Budget 2020</i>. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at <u>https://doi.org/10.5194/essd-12-3269-2020</u>
	SV3.2	GCP-Global Carbon Project 2020 / WEGCupd 2021
	Consumption -based CO2 emissions	 Friedlingstein et al. (2020). <i>Global Carbon Budget 2020</i>. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at https://doi.org/10.5194/essd-12-3269-2020
	SV3.3	WEGC/Kirc-etal 2021 (incl GCClv1 EPClin&floor-scen)
	Production- based CO2 emissions incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-GLO. DocID GCCIv1.2-GEM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/gem (see also the reference under SubVariable SV3.1 above) Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
	SV3.4	WEGC/Kirc-etal 2021 (incl GCCIv1 EPClin&floor-scen)
	consumption -based CO2 emissions incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-GLO. DocID GCCIv1.2-GEM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/gem</u> (see also the reference under SubVariable SV3.2 above) Kirchengast (2021). Simple budget-based linear & floor emission
		reduction path modeling following Williges et al. (2021) Fairness

		critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
V4. GHG annual emissions [MtCO ₂ eq]	Explanation: See SubVariables of the annual gree globally since 19 climate-relevan etc.) and are me 2050 are in this GtCO ₂ eq with a Compared to Va here for GHGs f land use change Land Use Change	the the explanation at the beginning of the Variable V3 block above—the this Variable V4 are constructed in exactly the same way but based on inhouse gas (GHG) emissions of countries, relevant country groups, and 290 rather than on CO ₂ emissions only. The GHG emissions include all t GHGs according to international accounting principles (also CH ₄ , N ₂ O, easured in Million tons of CO ₂ equivalent [MtCO ₂ eq]. The scenarios to case based on a remaining 2017-2050 global GHG budget of 1000 residual-floor annual global emission of 5 GtCO ₂ eq/yr. ariable V3, one additional amount-of-emissions SubVariable is available or most countries: the production-based GHG emissions from Land Use, e, which means to also count in the annual net emissions from Land Use, ge, and Forestry (LULUCF). These are sometimes negative in case the acts as net sink (SV4.2 emissions are then lower than those of SV4.1).
	UNFCCC & GCP	EmissionsDBs & WEGC 2021
	SV4.1	UNFCCC EmissionsDB 2020 / WEGCupd 2021
	Production- based GHG emissions	 United Nations Framework Convention on Climate Change (UNFCCC) (2020). Greenhouse Gas Inventory Data. Online at <u>https://di.unfccc.int/time_series</u>
	SV4.2 Production-	UNFCCC EmissionsDB 2020 / WEGCupd 2021
	based GHG emissions incl from Land use change	 United Nations Framework Convention on Climate Change (UNFCCC) (2020). Greenhouse Gas Inventory Data. Online at <u>https://di.unfccc.int/time_series</u>
	SV4.3	UNFCCC & GCP EmissionDBs 2020 / WEGCupd 2021
	-based GHG emissions	 United Nations Framework Convention on Climate Change (UNFCCC) (2020). Greenhouse Gas Inventory Data. Online at <u>https://di.unfccc.int/time_series</u> Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at <u>https://doi.org/10.5194/essd-12-3269-2020</u>
	SV4.4	WEGC/Kirc-etal 2021 (incl GCCIv1 EPClin&floor-scen)
	Production- based GHG emissions incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-GLO. DocID GCCIv1.2-GEM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/gem (see also the reference under SubVariable SV4.1 above) Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
	SV4.5	WEGC/Kirc-etal 2021 (incl GCCIv1 EPClin&floor-scen)
	Consumption -based GHG	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet

	emissions incl path2Paris	 GEM-GLO. DocID GCCIv1.2-GEM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/gem</u> (see also the references under SubVariable SV4.3 above) Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
V5. CO2 annual emissions per person [tCO ₂ /Person]	Explanation: This is one of the two primary amount-of-emissions-per-person variables of GEM-GLO, the one based on annual CO ₂ emissions of countries, relevant country groups, and globally since 1990 (except production-based CO ₂ emissions per person available from 1960). The per-person data of this variable are derived from dividing the amount-of-emissions data of Variable V3 by the respective population size data (Variable V7 below).	
	The SubVariable 5.2&5.4) annua [tCO ₂ /Person], e reduction scena SVs). The releva simple "linear re following Willig This model prov country or cour global CO ₂ budg GtCO ₂ /yr (i.e., s based populatio	es include production-based (SVs 5.1&5.3) and consumption-based (SVs I emissions per person measured in tons of CO ₂ per person either up to the latest year with data (first SVs) or also including a prio to 2050 compliant with the Paris climate goals ("incl path2Paris" ant amount-of-emission scenarios are modeled for GCClv1 according to a eduction & residual floor emission path model" of Kirchengast (2021) es et al. (2021) (except for SV5.3 for Austria as explained in GEM-AT). <i>vi</i> des 2017-2050 paths consistent with the CO ₂ budget allocated to a ettry group on an equal-per-person basis from a remaining 2017-2050 get of 700 GtCO ₂ with a residual-floor annual global emission of 3.5 ame data as for Variable V3, just divided by the respective scenario- on size data of Variable V7).
	GCP-EmissionD	B & UN-PopDB 2020 & WEGC 2021
	SV5.1 Production-	GCP-EmDB & UN-PopDB 2020 / WEGCupd 2021 Friedlingstein et al. (2020). Global Carbon Budget 2020.
	based CO2 emissions per Person	Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at https://doi.org/10.5194/essd-12-3269-2020
		 United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u>
	SV5.2	GCP-EmDB & UN-PopDB 2020 / WEGCupd 2021
SV5.3 Production- based CO2 emissions Production- based CO2 emissions per Person incl path2Paris	consumption -based CO2 emissions per Person	 Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at <u>https://doi.org/10.5194/essd-12-3269-2020</u> United Nations (UN) (2020). Population Dynamics. Department of
		Economic and Social Affairs. Online at https://population.un.org/wpp/Download/Standard/Population/
	SV5.3 Production-	WEGC/Kirc-etal 2021 (incl GCClv1 EPClin&floor-scen)
	based CO2 emissions per Person incl path2Paris	Kirchengast and Kohlfürst (2021). <i>Graz Climate Change Indicators</i> (<i>GCCI</i>) <i>Content and References Information Sheets—InfoSheet</i> <i>GEM-GLO</i> . DocID GCCIv1.2-GEM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/gem</u> (see also the references under SubVariable SV5.1 above)

Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request) GC/Kirc-etal 2021 (incl GCClv1 EPClin&floor-scen) Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-GLO. DocID GCClv1.2-GEM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/gem (see also the references under SubVariable SV5.2 above)	SV5.4 Consumption -based CO2 emissions per Person incl path2Paris		
reduction path modeling following Williges et al. (2021) Fairness ritically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)			
explanation at the beginning of the Variable V5 block above—the 'ariable V5 are constructed in exactly the same way but based on se gas (GHG) emissions of countries, relevant country groups, and ther than on CO ₂ emissions only. The GHG emissions include all is according to international accounting principles (also CH ₄ , N ₂ O, r-person basis, measured in tons of CO ₂ equivalent per person scenarios to 2050 are in this case based on a remaining 2017-2050 1000 GtCO ₂ eq with a residual-floor annual global emission of 5 e V5, one additional amount-of-emissions-per-person SubVariable iHGs for most countries: the production-based GHG emissions per n land use change, which means to also count in the annual net Use, Land Use Change, and Forestry (LULUCF). These are negative ector acts as net sink (in which case the SV6.2 emissions are then V6.1).	Explanation: See SubVariables of the annual gree globally since 19 climate-relevan etc.) and are, or [tCO ₂ eq/Person global GHG bud GtCO ₂ eq/yr. Compared to Va is available here person including emissions from in case the LULU lower than thos	V6. GHG annual emissions per person [tCO ₂ eq/Person]	
; & UN-PopDB 2020 & WEGC 2021	UNFCCC&GCP-E		
CCC-EmDB & UN-PopDB 2020 / WEGCupd 2021	SV6.1		
Jnited Nations Framework Convention on Climate Change UNFCCC) (2020). <i>Greenhouse Gas Inventory Data</i> . Online at <u>https://di.unfccc.int/time_series</u> Jnited Nations (UN) (2020). <i>Population Dynamics</i> . Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u>	production- based GHG emissions per Person		
CCC-EmDB & UN-PopDB 2020 / WEGCupd 2021	SV6.2		
Jnited Nations Framework Convention on Climate Change UNFCCC) (2020). <i>Greenhouse Gas Inventory Data</i> . Online at <u>https://di.unfccc.int/time_series</u> Jnited Nations (UN) (2020). <i>Population Dynamics</i> . Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u> CCCC&GCP-EmDBs & UN-PopDB 2020 / WEGCupd 2021	Production- based GHG emissions per Person incl from Land use change		
Jnited Nations (UN) (2020). <i>Population Dynamics</i> . Depa Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Po</u> CCC&GCP-EmDBs & UN-PopDB 2020 / WEGCupd 2021	per Person incl from Land use change		

S C -I e p	SV6.3 Consumption -based GHG emissions per Person	 United Nations Framework Convention on Climate Change (UNFCCC) (2020). Greenhouse Gas Inventory Data. Online at https://di.unfccc.int/time_series Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at https://doi.org/10.5194/essd-12-3269-2020 United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at https://population.up.org/upp/Doupload/Standard/Depulation (
	SV6.4	WEGC/Kirc-etal 2021 (incl GCClv1 EPClin&floor-scen)
	Production- based GHG emissions per Person incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-GLO. DocID GCCIv1.2-GEM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/gem (see also the references under SubVariable SV6.1 above) Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
	SV6.5	WEGC/Kirc-etal 2021 (incl GCClv1 EPClin&floor-scen)
Con -ba em per inc pat	Consumption - -based GHG emissions per Person incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-GLO. DocID GCClv1.2-GEM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/gem (see also the references under SubVariable SV6.3 above) Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
	<u> </u>	
V7. GHG annual concentrations [ppm]	Explanation: This variable provides annual global greenhouse gas (GHG) concentration in the atmosphere since 1960 in two forms: 1. CO_2 -equivalent concentration (SV7.1), which is the concentration that CO_2 would have in the air if the total radiative forcing of all GHGs (incl. also CH_4 , N_2O , etc.) would come from CO_2 only, and 2. the concentration of just CO_2 , which is the main GHG that has contributed about 80% of the radiative forcing increase since 1990 that drives global warming (see under CWM-GLO for a range of global warming-related variables, including radiative forcing). The units of parts per million [ppm], used for expressing concentrations of trace gases such as CO_2 in the air, denote the number of molecules of a trace gas per million of tot air molecules. In Earth's atmosphere about 99% of this total are made up by molecula nitrogen (N_2) and oxygen (O_2), termed the main constituents of the air.	
	NOAA 2020 & N	leinetal 2017 & Etmietal 2016 & WEGC 2021
	SV7.1 CO2- equivalent concentration (all GHGs)	 NOAA 2020 & Meinsh-etal 2017 & Etmin-etal 2016 / WEGCupd 2021 Meinshausen et al. (2017). <i>Historical greenhouse gas</i> concentrations for climate modelling (CMIP6). Geosci. Model Dev., 10, 2057-2116. Online at <u>https://doi.org/10.5194/gmd-10-2057-2017</u> Butler and Montzka-NOAA (2020). <i>The NOAA Annual Greenhouse</i> Gas Index (AGGI). Online at https://aml.poop.gov/aggi/aggi.html

	SV7.2 CO2 concentration (no other GHGs)	 Etminan et al. (2016). Radiative forcing of carbon dioxide, methane, and nitrous oxide: A significant revision of the methane radiative forcing. Geophys. Res. Lett., 43, 12,614–12,623. Online at https://doi.org/10.1002/2016GL071930 NOAA 2020 & Meinsh-etal 2017 / WEGCupd 2021 Meinshausen et al. (2017). Historical greenhouse gas concentrations for climate modelling (CMIP6). Geosci. Model Dev., 10, 2057-2116. Online at https://doi.org/10.5194/gmd-10-2057-2017 Butler and Montzka-NOAA (2020). The NOAA Annual Greenhouse Gas Index (AGGI). Online at https://gml.noaa.gov/aggi/aggi.html
V8. Population size [No. of Persons]	 <i>Explanation:</i> This auxiliary variable of GEM-GLO provides the population size of countries, relevant country groups, and globally since 1960. It expresses on an annual basis the number of residents, counted as [No. of Persons], who live in countries, relevant country groups, and globally. While the annual population sizes up to the latest year with data (SV7.1) are based on population census data collected by the UN, the scenario data to 2050 (SV7.2) are drawn from the UN population dynamics database, using the "medium estimate" scenario. In this scenario the global population rises from about 7.7 to 9.7 billion over 2019 to 2050 while, for example, the European one slightly decreases from about 615 to 590 million residents. 	
	UN PopulationD	B 2020 & WEGCupd 2021
	SV8.1 Past-to- present population size	 UN PopDB 2020 / WEGCupd 2021 United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at https://population.un.org/wpp/Download/Standard/Population/
	SV8.2	UN PopDB 2020 / WEGCupd 2021
	Scenario- based population size	 United Nations (UN) (2020). <i>Population Dynamics</i>. Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u>
V9. Economic data [Billions of EUR]	Explanation:This auxiliary variable provides economic indicators since 1atasubvariables. Both of these are inflation-adjusted which is marked by theUR]SV9.1 describes the real gross domestic product (GDP) which is the value and services produced or exerted within a country's borders. For aggrega country level data is summed up. SV9.2 shows real purchasing power pai which is GDP in terms of an exchange rate between countries that accou value of a fixed basket of goods rather than the market exchange rates. I is less volatile than the market exchange rate. Both quantities are given i	
	WEO/IMF Econo	mic Data 2021
	SV9.1	WEO/IMF Economic Data 2021
	Gross Domestic	 International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at

	Product (real GDP)	 <u>https://www.imf.org/en/Publications/WEO/weo-</u> <u>database/2021/October</u> International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at <u>https://data.imf.org</u>
	SV9.2	WEO/IMF Economic Data 2021
	Purchasing Power Parity (real PPP)	 International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo-</u> <u>database/2021/October</u> International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at <u>https://data.imf.org</u>
V10. Economic data per person [EUR per person]	Explanation: This diagnostic variable shows economic data on a per capita basis. It us the same data as described in Variable V9 divided by the population data in Variable This makes data between countries easier to compare. The values are given in Euros person (EUR per person). SV10.1 shows GDP per person and SV10.2 shows PPP per person.	
	WEO/IMF 2021	& UN-PopDB 2020/WEGCupd 2021
	SV10.1	WEO/IMF 2021 & UN-PopDB 2020/WEGCupd 2021
	Gross Domestic Product (realGDP) per Person	 International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at https://www.imf.org/en/Publications/WEO/weo- database/2021/October International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at https://data.imf.org United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at https://population.un.org/wpp/Download/Standard/Population/
	SV10.2	WEO/IMF 2021 & UN-PopDB 2020/WEGCupd 2021
	Purchasing Power Parity (real PPP) per Person	 International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo-</u><u>database/2021/October</u> International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at https://data.imf.org United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u>
V/1.1	Fundamentians T	
CO2 emissions per GDP and PPP	Explanation: This variable is one of two variables in GCCI that compares emissions and economy. Here the CO2 emission data from Variable V3 are divided by the GDP and PPP data to show how economy and emissions are related. CO2 emissions per GDP and PPP are measured in tonnes of CO2 per million Euro (tCO2pMEUR). Details on the emission	

[Tonnes of CO2 per Million EUR]	calculations can be read in the description of V3. The four subvariables of include production- and consumption-based emissions per GDP and PPP, respectively.		
	GCP-EmissionDB & WEO/IMF EconData 2021 & WEGC2021		
	SV11.1	GCP-EmDB & WEO/IMF2021 & WEGC2021	
	Production- based CO2 emissions per GDP	 Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at https://doi.org/10.5194/essd-12-3269-2020 International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at https://data.imf.org International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at https://www.imf.org/en/Publications/WEO/weo- database/2021/October United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at https://population.un.org/wpp/Download/Standard/Population/ 	
	SV11.2	GCP-EmDB & WEO/IMF2021 & WEGC2021	
	Consumption -based CO2 emissions per GDP	 Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at https://doi.org/10.5194/essd-12-3269-2020 International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at https://data.imf.org International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at https://www.imf.org/en/Publications/WEO/weo- database/2021/October United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at https://population.un.org/wpp/Download/Standard/Population/ 	
	SV11.3	GCP-EmDB & WEO/IMF2021 & WEGC2021	
	based CO2 emissions per PPP	 Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at <u>https://doi.org/10.5194/essd-12-3269-2020</u> International Monetary Fund (IMF) (2021). <i>Exchange rates incl.</i> <i>Effective exchange rates</i>. Online at https://data.imf.org International Monetary Fund (IMF) (2021). <i>World Economic</i> <i>Outlook: Recovery during a Pandemic—Health Concerns, Supply</i> <i>Disruptions, Price Pressures</i>. International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo- database/2021/October</u> United Nations (UN) (2020). <i>Population Dynamics</i>. Department of Economic and Social Affairs. Online at <u>https://population.up.org/wop/Download/Standard/Dopulation/</u> 	
		GCP-EmDB & WEO/IMF2021 & WEGC2021	

	SV11.4 Consumption -based CO2 emissions per PPP	 Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at <u>https://doi.org/10.5194/essd-12-3269-2020</u> International Monetary Fund (IMF) (2021). <i>Exchange rates incl.</i> <i>Effective exchange rates</i>. Online at https://data.imf.org International Monetary Fund (IMF) (2021). <i>World Economic</i> <i>Outlook: Recovery during a Pandemic—Health Concerns, Supply</i> <i>Disruptions, Price Pressures</i>. International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo- database/2021/October</u> United Nations (UN) (2020). <i>Population Dynamics</i>. Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u>
V12.	Explanation: Th	is is the second emission-per-economy variable and it is calculated in
V12.IGHG emissionstper GDP and PPPt[Tonnes of CO2tper Million EUR]t	<i>Explanation:</i> The same mann the emission ca GDP and PPP ar The four subvar and PPP, respectively.	er as Variable V11 but using GHG emissions from Variable V4. Details on lculations can be read in the description of V4. The GHG emissions per e given in tonnes of CO2 equivalents per million Euro (tCO2eqpMEUR). iables include production- and consumption-based emissions per GDP ctively.
	UNFCCC & GCP-	EmDB & WEO/IMF EconData 2021 & WEGC2021
	SV12.1 Production-	UNFCCC-EmDB & WEO/IMF 2021 & WEGC2021
	per GDP	 United Nations Framework Convention on Climate Change (UNFCCC) (2020). Greenhouse Gas Inventory Data. Online at https://diunfccc.int/time_series International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at https://data.imf.org International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at https://www.imf.org/en/Publications/WEO/weo-database/2021/October United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at https://population.un.org/wpp/Download/Standard/Population/
	SV12.2 Consumption	UNFCCC-EmDB & WEO/IMF 2021 & WEGC2021
	-based GHG emissions per GDP	 United Nations Framework Convention on Climate Change (UNFCCC) (2020). Greenhouse Gas Inventory Data. Online at https://diunfccc.int/time_series International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at https://data.imf.org International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at https://www.imf.org/en/Publications/WEO/weo-database/2021/October United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at https://population.un.org/wpp/Download/Standard/Population/

SV12.3	UNFCCC-EmDB & WEO/IMF 2021 & WEGC2021
Production-	
based GHG emissions per PPP	 United Nations Framework Convention on Climate Change (UNFCCC) (2020). Greenhouse Gas Inventory Data. Online at <u>https://di.unfccc.int/time_series</u>
	 International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at https://data.imf.org International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at https://www.imf.org/en/Publications/WEO/weo- database/2021/October United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at https://population.un.org/wpp/Download/Standard/Population/
SV12.4	UNFCCC-EmDB & WEO/IMF 2021 & WEGC2021
Consumption -based GHG emissions per PPP	 United Nations Framework Convention on Climate Change (UNFCCC) (2020). Greenhouse Gas Inventory Data. Online at <u>https://di.unfccc.int/time_series</u> International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at <u>https://data.imf.org</u> International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo- database/2021/October</u> United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at
	https://population.un.org/wpp/Download/Standard/Population/

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GEM-EUR Content and References

GEM-GHG Emissions Monitoring – Domain Europe

Version GCCIv1.2 Information Sheet on the GEM-EUR Variables Tabular List of Variables & SubVariables together with explanations and data source references

How-to-Read Template: Format and content of the information per Variable in the Table below

VN. Variable N	Explanation: brief explanation of what Variable N expresses and optionally (e.g., in case of an index variable in units [%]) how it is computed			
[Unit]	<datasourceshortcite string="" vn=""> (as cited within the chart at the GCCI data portal)</datasourceshortcite>			
	SVN.1	<datesources string="" svn.1=""> (from GCCIv1 SV definitions file)</datesources>		
	Name	Reference(s) to the data source(s) for SVN.1, incl DOIs, Weblinks, etc, as available (one or more detailed references)		
	SVN.2 SubVariable <i>N</i> .2 Name	<datesources string="" svn.2=""> (from GCCIv1 SV definitions file)</datesources>		
		Reference(s) to the data source(s) for SVN.2, incl DOIs, Weblinks, etc, as available (one or more detailed references)		
	SVN.3	<datesources string="" svn.3=""> (from GCCIv1 SV definitions file)</datesources>		
	Name	Reference(s) to the data source(s) for SVN.3, incl DOIs, Weblinks, etc, as available (one or more detailed references)		
	SVN.4	<datesources string="" svn.4=""> (from GCCIv1 SV definitions file)</datesources>		
	Name	Reference(s) to the data source(s) for SVN.4, incl DOIs, Weblinks, etc, as available (one or more detailed references)		

GEM-EUR Information Sheet Table: GEM-GHG Emissions Monitoring – Domain Europe

Variable (V) Name	SubVariable (SV) Name	Variable Explanation and Data Source References
V1. CO2-based climate change (CC) mitigation index [%]	Explanation: The on annual CO ₂ e success of emiss average 1990-19 The SubVariable as well as the pre emission reduct or also including ("incl path2Paris "linear reduction Williges et al. (2 model provides (or country grou CO ₂ budget of 7 Formula for the (based on the pre Index(Year i) [%] The main GCCI in indicates success neutrality) while The complement	is is one of the two primary index variables of GEM-EUR, the one based missions of Europe, its countries, and the EU since 1990. It indicates the ion reductions in any given year as a percentage against the annual- 394 CO ₂ emissions ("Em(Year i)" vs "AvgEm(1990-1994)"). Is include the main GCCI climate change mitigation index (SVs 1.1&1.2) oduction-based (SVs 1.3&1.5) and consumption-based (SVs 1.4&1.6) ion indices, respectively, either up to the latest year with data (first SVs) g a reduction scenario to 2050 compliant with the Paris climate goals "SVs). The scenarios are modeled for GCCIv1 according to a simple n & residual floor emission path model" of Kirchengast (2021) following 021) (except for SVs 1.2&1.5 for Austria as explained in GEM-AT). This 2017-2050 paths consistent with the CO ₂ budget allocated to a country up) on an equal-per-person basis from a remaining 2017-2050 global 00 GtCO ₂ with a residual-floor annual global emission of 3.5 GtCO ₂ /yr. GCCI climate change mitigation index gauging emission reductions: roduction-based emission data) I = 100 x [Em(Year <i>i</i>) / AvgEm(1990-1994) – 1] production- and consumption-based emission reduction indices: I = 100 x [Em(Year <i>i</i>) / AvgEm(1990-1994)] ndex hence expresses the level of reductions against 0% near 1990. It s for achieving percentage values below 0% towards –100% (climate e it indicates failure by values that stick above 0% or even increase. tary two indices rather gauge the changes against 100% near 1990.
	WEGC-GCCI 202	1 & EEA-Eurst-GCP-EmDBs 2020
	SV1.1 GCCI CC mitigation index CO2 emission reduction (goal -100% vs 1990-94=0%)	 WEGC-GCCI/Kirc-etal 2021 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/europe/gem (see under "Explanation" above on the index computation)
	SV1.2	WEGC-GCCI/Kirc-etal 2021 (incl GCCIv1 EPClin&floor-scen)
	mitigation index CO2 emission reduction incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/europe/gem</u> Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
	SV1.3 Production	WEGC-GCCI/Kirc-etal 2021 & GCP-GloCarbProj 2020 (also EEA-Eurst)
	based CO2 emission reduction index	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/europe/gem</u> (see under "Explanation" above on the index computation)

		 Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at <u>https://doi.org/10.5194/essd-12-3269-2020</u>
	SV1.4	WEGC-GCCI/Kirc-etal 2021 & GCP-GloCarbProj 2020
	consumption- based CO2 emission reduction index	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/europe/gem</u> (see under "Explanation" above on the index computation) Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at <u>https://doi.org/10.5194/essd-12-3269-2020</u>
	SV1.5	WEGC-GCCI/Kirc-etal 2021 (incl GCCIv1 EPClin&floor-scen)
	Production- based CO2 emission reduction index incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/europe/gem Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ, Change in rev. (until online, available on request)
	SV1.6	WEGC-GCCI/Kirc-etal 2021 (incl GCClv1 EPClin&floor-scen)
	Consumption- based CO2 emission reduction index incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/europe/gem</u> Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness artigally conditions the carbon budget allocation generation
		Global Environ. Change in rev. (until online, available on request)
V2. GHG-based climate change (CC) mitigation index [%]	Explanation: See SubVariables of the annual green 1990 rather than The GHG emission accounting print equivalent [MtC case based on a residual-floor ar	e the explanation at the beginning of the Variable V1 block above—the this Variable V2 are constructed in exactly the same way but based on nhouse gas (GHG) emissions of Europe, its countries, and the EU since n on CO_2 emissions only. ons include all climate-relevant GHGs according to international ciples (also CH_4 , N_2O , etc.) and are measured in Million tons of CO_2 O_2eq] (see under Variable V4 below). The scenarios to 2050 are in this remaining 2017-2050 global GHG budget of 1000 GtCO ₂ eq with a nual global emission of 5 GtCO ₂ eq/yr.
	WEGC-GCCI 202	1 & EEA-Eurost-GCP EmDBs 2020
	SV2.1 GCCI CC mitigation index GHG emission reduction	 WEGC-GCCI/Kirc-etal 2021 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/europe/gem (see under "Explanation" above on the index computation)

	(goal -100% vs 1990-94=0%)	
	SV2.2	WEGC-GCCI/Kirc-etal 2021 (incl GCCIv1 EPClin&floor-scen)
	mitigation index GHG emission reduction incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/europe/gem Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
	SV2.3	WEGC-GCCI/Kirc-etal 2021 & EEA-Eurostat EmissionsDB 2020
	Production- based GHG emission reduction index	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/europe/gem</u> (see under "Explanation" above on the index computation)
		 European Environment Agency (EEA) (2020). Greenhouse gas emissions by source sector. European Statistical Office (Eurostat). Online at https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env air gge⟨=en
	SV2.4 Consumption- based GHG emission reduction index	WEGC-GCCI/Kirc-etal 2021 & EEA-Eurostat & GCP EmDB 2020
		 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/europe/gem</u> (see under "Explanation" above on the index computation)
		 European Environment Agency (EEA) (2020). Greenhouse gas emissions by source sector. European Statistical Office (Eurostat). Online at <u>https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env</u> air gge⟨=en Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst.
		Sci. Data, 12, 3269–3340, 2020. Online at https://doi.org/10.5194/essd-12-3269-2020
	SV2.5 Production-	WEGC-GCCI/Kirc-etal 2021 (incl GCClv1 EPClin&floor-scen)
	based GHG emissions incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/europe/gem Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
		WEGC-GCCI/Kirc-etal 2021 (incl GCCIv1 EPClin&floor-scen)

	SV2.6 Consumption- based GHG emissions incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/europe/gem Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
vs. CO2 annual emissions [MtCO ₂]	Explanation: Th EUR, the one ba 1990 (except pro- The SubVariable 3.2&3.4) annual latest year with with the Paris cl The scenarios ar residual floor en (2021) (except fr 2050 paths cons an equal-per-pe with a residual-f	Is is one of the two primary amount-of-emissions variables of GEM- sed on annual CO_2 emissions of Europe, its countries, and the EU since oduction-based CO_2 emissions being available from 1960). Its include production-based (SVs 3.1&3.3) and consumption-based (SVs emissions measured in Million tons of CO_2 [MtCO ₂], either up to the data (first SVs) or also including a reduction scenario to 2050 compliant imate goals ("incl path2Paris" SVs). The modeled for GCCIv1 according to a simple "linear reduction & nission path model" of Kirchengast (2021) following Williges et al. or SV3.3 for Austria as explained in GEM-AT). This model provides 2017- sistent with the CO_2 budget allocated to a country (or country group) on rson basis from a remaining 2017-2050 global CO_2 budget of 700 GtCO ₂ floor annual global emission of 3.5 GtCO ₂ /yr.
	GCP-GlobCarbPr	roj & WEGC Kircetal 2021
	SV3.1 Production- based CO2 emissions	 GCP-Global Carbon Project 2020 / WEGCupd 2021 Friedlingstein et al. (2020). <i>Global Carbon Budget 2020</i>. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at <u>https://doi.org/10.5194/essd-12-3269-2020</u>
	SV3.2	GCP-Global Carbon Project 2020 / WEGCupd 2021
	Consumption- based CO2 emissions	 Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at https://doi.org/10.5194/essd-12-3269-2020
	SV3.3	WEGC/Kirc-etal 2021 (incl GCCIv1 EPClin&floor-scen)
Prod base emis path SV3 Cons base emis path	Production- based CO2 emissions incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/europe/gem (see also the reference under SubVariable SV3.1 above) Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
	SV3.4	WEGC/Kirc-etal 2021 (incl GCCIv1 EPClin&floor-scen)
	Consumption- based CO2 emissions incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/europe/gem (see also the reference under SubVariable SV3.2 above) Kirchengast (2021). Simple budget-based linear & floor emission reduction with modeling following Willing and the following States.

		critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
V4. GHG annual emissions [MtCO ₂ eq]	Explanation: See SubVariables of the annual gree 1990 rather that GHGs according measured in Mil case based on a residual-floor ar Compared to Va here for GHGs fo land use change Land Use Chang LULUCF sector a	e the explanation at the beginning of the Variable V3 block above—the this Variable V4 are constructed in exactly the same way but based on nhouse gas (GHG) emissions of Europe, its countries, and the EU since n on CO ₂ emissions only. The GHG emissions include all climate-relevant to international accounting principles (also CH ₄ , N ₂ O, etc.) and are llion tons of CO ₂ equivalent [MtCO ₂ eq]. The scenarios to 2050 are in this remaining 2017-2050 global GHG budget of 1000 GtCO ₂ eq with a nnual global emission of 5 GtCO ₂ eq/yr. ariable V3, one additional amount-of-emissions SubVariable is available for most countries: the production-based GHG emissions from Land Use, e, and Forestry (LULUCF). These are sometimes negative in case the cts as net sink (SV4.2 emissions are then lower than those of SV4.1).
	EEA-Eurostat-GO	CP EmDBs & WEGC Kircetal 2021
	SV4.1	EEA-Eurostat EmissionsDB 2020 / WEGCupd 2021
	Production- based GHG emissions	 European Environment Agency (EEA) (2020). Greenhouse gas emissions by source sector. European Statistical Office (Eurostat). Online at <u>https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env</u> air gge⟨=en
	SV4.2	EEA-Eurostat EmissionsDB 2020 / WEGCupd 2021
	Production- based GHG emissions incl from Land use change	 European Environment Agency (EEA) (2020). Greenhouse gas emissions by source sector. European Statistical Office (Eurostat). Online at <u>https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env</u> air_gge⟨=en
	SV4.3	EEA-Eurostat & GCP EmissionDBs 2020 / WEGCupd 2021
	Consumption- based GHG emissions	 European Environment Agency (EEA) (2020). Greenhouse gas emissions by source sector. European Statistical Office (Eurostat). Online at <u>https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env</u> air gge⟨=en Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at <u>https://doi.org/10.5194/essd-12-3269-2020</u>
	SV4.4	WEGC/Kirc-etal 2021 (incl GCCIv1 EPClin&floor-scen)
	Production- based GHG emissions incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/europe/gem (see also the reference under SubVariable SV4.1 above) Kirchengast (2021). Simple budget-based linear & floor emission
		reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)

	SV4.5	WEGC/Kirc-etal 2021 (incl GCCIv1 EPClin&floor-scen)
	Consumption- based GHG emissions incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/europe/gem</u> (see also the references under SubVariable SV4.3 above) Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
V5. CO2 annual emissions per person [tCO ₂ /Person]	<i>Explanation:</i> The of GEM-EUR, the EU since 1990 (e The per-person data of Variable The SubVariable 5.2&5.4) annual [tCO ₂ /Person], e reduction scena SVs). The releval simple "linear refollowing Willige This model prov country (or cour global CO ₂ budg GtCO ₂ /yr (i.e., sa based populatio	is is one of the two primary amount-of-emissions-per-person variables is one based on annual CO ₂ emissions of Europe, its countries, and the except production-based CO ₂ emissions per person available from 1960). data of this variable are derived from dividing the amount-of-emissions V3 by the respective population size data (Variable V7 below). is include production-based (SVs 5.1&5.3) and consumption-based (SVs emissions per person measured in tons of CO ₂ per person either up to the latest year with data (first SVs) or also including a rio to 2050 compliant with the Paris climate goals ("incl path2Paris" int amount-of-emission scenarios are modeled for GCClv1 according to a eduction & residual floor emission path model" of Kirchengast (2021) es et al. (2021) (except for SV5.3 for Austria as explained in GEM-AT). ides 2017-2050 paths consistent with the CO ₂ budget allocated to a ntry group) on an equal-per-person basis from a remaining 2017-2050 et of 700 GtCO ₂ with a residual-floor annual global emission of 3.5 ame data as for Variable V3, just divided by the respective scenario- n size data of Variable V7). DB & PopDB & WEGC Kircetal 2021
	SV5.1	GCP-EmDB & Eurostat-UN-PDB 2020 / WEGCupd 2021
	Production- based CO2 emissions per Person	 Friedlingstein et al. (2020). <i>Global Carbon Budget 2020</i>. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at <u>https://doi.org/10.5194/essd-12-3269-2020</u> European Environment Agency (EEA) (2020). <i>Demographic change</i> - <i>Demographic balance and crude rates at national level</i>. European Statistical Office (Eurostat). Online at <u>https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=dem</u> o gind⟨=de United Nations (UN) (2020). <i>Population Dynamics</i>. Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u>
	SV5.2	GCP-EmDB & Eurostat-UN-PDB 2020 / WEGCupd 2021
	Consumption- based CO2 emissions per Person	 Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at https://doi.org/10.5194/essd-12-3269-2020 European Environment Agency (EEA) (2020). Demographic change - Demographic balance and crude rates at national level. European Statistical Office (Eurostat). Online at https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=dem o gind⟨=de

-		 United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u>
	SV5.3	WEGC/Kirc-etal 2021 (incl GCClv1 EPClin&floor-scen)
	Production- based CO2 emissions per Person incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/europe/gem</u> (see also the references under SubVariable SV5.1 above) Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
	SV5.4	WEGC/Kirc-etal 2021 (incl GCClv1 EPClin&floor-scen)
Consumption based CO2 emissions p Person incl path2Paris	Consumption- based CO2 emissions per Person incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/europe/gem</u> (see also the references under SubVariable SV5.2 above)
		 Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
	1	
V6. GHG annual emissions per person [tCO2eq/Person]	Explanation: See SubVariables of the annual green 1990 rather than GHGs according per-person basis scenarios to 205 of 1000 GtCO ₂ ec Compared to Va is available here person including emissions from 1 in case the LULL lower than those	e the explanation at the beginning of the Variable V5 block above—the this Variable V5 are constructed in exactly the same way but based on nhouse gas (GHG) emissions of Europe, its countries, and the EU since n on CO ₂ emissions only. The GHG emissions include all climate-relevant to international accounting principles (also CH ₄ , N ₂ O, etc.) and are, on a s, measured in tons of CO ₂ equivalent per person [tCO ₂ eq/Person]. The O are in this case based on a remaining 2017-2050 global GHG budget q with a residual-floor annual global emission of 5 GtCO ₂ eq/yr. Iriable V5, one additional amount-of-emissions-per-person SubVariable for GHGs for most countries: the production-based GHG emissions per g from land use change, which means to also count in the annual net Land Use, Land Use Change, and Forestry (LULUCF). These are negative JCF sector acts as net sink (in which case the SV6.2 emissions are then e of SV6.1).
	l	
	EEA-EU-UN- GCF	P EmDB&PopDB 2020 & WEGC Kircetal 2021
	EEA-EU-UN- GCF SV6.1	P EmDB&PopDB 2020 & WEGC Kircetal 2021 EEA-Eurostat-UN EmDB & PopDB 2020 / WEGCupd 2021

		 United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u>
	SV6.2	EEA-Eurostat-UN EmDB & PopDB 2020 / WEGCupd 2021
	Production- based GHG emissions per Person incl from Land use change	 European Environment Agency (EEA) – Emissions (2020). Greenhouse gas emissions by source sector. European Statistical Office (Eurostat). Online at <u>https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env</u> <u>air gge⟨=en</u> European Environment Agency (EEA) – Demographics (2020). Demographic change - Demographic balance and crude rates at national level. European Statistical Office (Eurostat). Online at <u>https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=dem</u> <u>o gind⟨=de</u> United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u>
	SV6.3	EEA-Eurostat-UN-GCP EmDB & PopDB 2020 / WEGCupd 2021
	consumption- based GHG emissions per Person	 European Environment Agency (EEA) – Emissions (2020). Greenhouse gas emissions by source sector. European Statistical Office (Eurostat). Online at https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=envair_gge⟨=en
		 Friedlingstein et al. (2020). <i>Global Carbon Budget 2020</i>. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at <u>https://doi.org/10.5194/essd-12-3269-2020</u>
		 European Environment Agency (EEA) – Demographics (2020). Demographic change - Demographic balance and crude rates at national level. European Statistical Office (Eurostat). Online at <u>https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=dem</u> o_gind⟨=de
		 United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u>
	SV6.4 Production- based GHG emissions per Person incl path2Paris	WEGC/Kirc-etal 2021 (incl GCCIv1 EPClin&floor-scen)
		 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/europe/gem</u> (see also the references under SubVariable SV6.1 above) Kirchengast (2021). Simple budget-based linear & floor emission
		reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
	SV6.5 Consumption-	WEGC/Kirc-etal 2021 (incl GCCIv1 EPClin&floor-scen)
	based GHG emissions per	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-EUR. DocID GCCIv1.2-GEM-EUR-Apr2022, Wegener Center,

V7. Population size [No. of Persons]	Person incl path2Paris Explanation: Th its countries, an residents, count While the annua population cens are drawn from scenario. In this 2019 to 2050 wh residents (and w	 Univ. of Graz, Austria. Online at www.gcci.earth/europe/gem (see also the references under SubVariable SV6.3 above) Kirchengast (2021). Simple budget-based linear&floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request) is auxiliary variable of GEM-EUR provides the population size of Europe, d the EU since 1960. It expresses on an annual basis the number of ed as [No. of Persons], who live in Europe, its countries, and the EU. Il population sizes up to the latest year with data (SV7.1) are based on us data collected by the EEA and UN, the scenario data to 2050 (SV7.2) the UN population dynamics database, using the "medium estimate" scenario the global population rises from about 7.7 to 9.7 billion over hile the European one slightly decreases from about 615 to 590 million rithin Europe the EU-27 from about 445 to 425 million people).
	Eurostat & UN P	opDBs 2020 & WEGCupd 2021
	SV7.1	Eurostat & UN PopDB 2020 / WEGCupd 2021
	Past-to- present population size	 European Environment Agency (EEA) (2020). Demographic change Demographic balance and crude rates at national level. European Statistical Office (Eurostat). Online at https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=dem_o_gind⟨=de United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at https://population.un.org/wpp/Download/Standard/Population/
	SV7.2	UN PopDB 2020 / WEGCupd 2021
	Scenario- based population size	 United Nations (UN) (2020). <i>Population Dynamics</i>. Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u>
V8. Economic Data [Billions of EUR]	Explanation: This auxiliary variable provides economic indicators since 1999 in its two subvariables. Both of these are inflation-adjusted which is marked by the word real. SV8.1 describes the real gross domestic product (GDP) which is the value of all goods and services produced or exerted within a country's borders. For aggregated regions the country level data is summed up. SV8.2 shows real purchasing power parity (PPP), which is GDP in terms of an exchange rate between countries that accounts for the value of a fixed basket of goods rather than the market exchange rates. In this manner it is less volatile than the market exchange rate. Both quantities are given in Euros (EUR).	
	WEO/IMF Econo	omic Data 2021
	SV8.1 Gross Domestic Product (real GDP)	 WEO/IMF Economic Data 2021 International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo- database/2021/October</u>

		 International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at <u>https://data.imf.org</u>
	SV8.2	WEO/IMF Economic Data 2021
	Power Parity (real PPP)	 International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo- database/2021/October</u> International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at <u>https://data.imf.org</u>
V9. Economic Data per Person [EUR per person]	<i>Explanation:</i> This the same data and V8. This makes of Euros per person per person per person.	is diagnostic variable shows economic data on a per capita basis. It uses s described in Variable V8 divided by the population data in Variable data between countries easier to compare. The values are given in n (EUR per person). SV9.1 shows GDP per person and SV9.2 shows PPP
	WEO/IMF 2021	& UN-PopDB 2020/WEGCupd 2021
	SV9.1	WEO/IMF 2021 & UN-PopDB 2020/WEGCupd 2021
	Gross Domestic Product (real GDP) per Person	 International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo-</u><u>database/2021/October</u> International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at <u>https://data.imf.org</u> United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u>
	SV9.2 Purchasing Power Parity (real PPP) per Person	 WEO/IMF 2021 & UN-PopDB 2020/WEGCupd 2021 International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at https://www.imf.org/en/Publications/WEO/weo- database/2021/October International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at https://data.imf.org United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at https://www.imf.org/upp.(Download (Standard /Donulation (UN))
		https://population.un.org/wpp/Download/Standard/Population/
V10. CO2 emissions per GDP and PPP [Tonnes of CO2 per Million EUR]	Explanation: This variable is one of two variables in GCCI that compares emissions and economy. Here the CO2 emission data from Variable V3 are divided by the GDP and PPP data to show how economy and emissions are related. CO2 emissions per GDP and PPP are measured in tonnes of CO2 per million Euro (tCO2pMEUR). Details on the emission calculations can be read in the description of V3. The four subvariables include production- and consumption-based emissions per GDP and PPP, respectively.	

GCP-EmissionDB & WEO/IMF EconData 2021 & WEGC2021		
SV10.1	GCP-EmDB & WEO/IMF2021 & WEGC2021	
Production- based CO2 emissions per GDP SV10.2	 Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at <u>https://doi.org/10.5194/essd-12-3269-2020</u> International Monetary Fund (IMF) (2021). <i>Exchange rates incl.</i> <i>Effective exchange rates</i>. Online at <u>https://data.imf.org</u> International Monetary Fund (IMF) (2021). <i>World Economic</i> <i>Outlook: Recovery during a Pandemic—Health Concerns, Supply</i> <i>Disruptions, Price Pressures</i>. International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo- database/2021/October</u> United Nations (UN) (2020). <i>Population Dynamics</i>. Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u> GCP-EmDB & WEO/IMF2021 & WEGC2021 	
based CO2 emissions per GDP	 Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at <u>https://doi.org/10.5194/essd-12-3269-2020</u> International Monetary Fund (IMF) (2021). <i>Exchange rates incl.</i> <i>Effective exchange rates</i>. Online at <u>https://data.imf.org</u> International Monetary Fund (IMF) (2021). <i>World Economic</i> <i>Outlook: Recovery during a Pandemic—Health Concerns, Supply</i> <i>Disruptions, Price Pressures</i>. International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo- database/2021/October</u> United Nations (UN) (2020). <i>Population Dynamics</i>. Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u> 	
SV10.3 Production-	GCP-EmDB & WEO/IMF2021 & WEGC2021	
based CO2 emissions per PPP	 Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at <u>https://doi.org/10.5194/essd-12-3269-2020</u> International Monetary Fund (IMF) (2021). <i>Exchange rates incl.</i> <i>Effective exchange rates</i>. Online at <u>https://data.imf.org</u> International Monetary Fund (IMF) (2021). <i>World Economic</i> <i>Outlook: Recovery during a Pandemic—Health Concerns, Supply</i> <i>Disruptions, Price Pressures</i>. International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo- database/2021/October</u> United Nations (UN) (2020). <i>Population Dynamics</i>. Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u> 	
SV10.4 Consumption- based CO2 emissions per PPP	 GCP-EmDB & WEO/IMF2021 & WEGC2021 Friedlingstein et al. (2020). Global Carbon Budget 2020. Earth Syst. Sci. Data, 12, 3269–3340, 2020. Online at https://doi.org/10.5194/essd-12-3269-2020 	

		 International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at <u>https://data.imf.org</u> International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo- database/2021/October</u> United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u>
V11.	Explanation: Th	is is the second emission-per-economy variable and it is calculated in
GHG emissions per GDP and PPP [Tonnes of CO2 equivalent per Million EUR]	the same manne the emission cal GDP and PPP are The four subvar and PPP, respec	er as Variable V11 but using GHG emissions from Variable V4. Details on lculations can be read in the description of V4. The GHG emissions per e given in tonnes of CO2 equivalents per million Euro (tCO2eqpMEUR). iables include production- and consumption-based emissions per GDP tively.
	EEA EmDB & WI	EO/IMF EconData 2021 & WEGC2021
	SV11.1 Production	EEA EmDB & WEO/IMF 2021 & WEGC2021
	based GHG emissions per GDP	 European Environment Agency (EEA) (2020). Greenhouse gas emissions by source sector. European Statistical Office (Eurostat). Online at https://ec.europa.eu/eurostat/databrowser/product/page/ENV_A IR_GGE_custom_1618132 International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at https://data.imf.org International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at https://www.imf.org/en/Publications/WEO/weo- database/2021/October
	SV11.2	EEA EmDB & WEO/IMF 2021 & WEGC2021
	based GHG emissions per GDP	 European Environment Agency (EEA) (2020). Greenhouse gas emissions by source sector. European Statistical Office (Eurostat). Online at https://ec.europa.eu/eurostat/databrowser/product/page/ENV_A IR_GGE_custom_1618132 International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at https://data.imf.org International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at https://www.imf.org/en/Publications/WEO/weo- database/2021/October
	SV11.3 Production	EEA EmDB & WEO/IMF 2021 & WEGC2021
	based GHG	 European Environment Agency (EEA) (2020). Greenhouse gas emissions by source sector. European Statistical Office (Eurostat).

emissions per PPP	 Online at https://ec.europa.eu/eurostat/databrowser/product/page/ENV_A IR GGE custom 1618132 International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at https://data.imf.org International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at https://www.imf.org/en/Publications/WEO/weo- database/2021/October
SV11.4 Consumption-	EEA EmDB & WEO/IMF 2021 & WEGC2021
based GHG emissions per PPP	 European Environment Agency (EEA) (2020). Greenhouse gas emissions by source sector. European Statistical Office (Eurostat). Online at <u>https://ec.europa.eu/eurostat/databrowser/product/page/ENV_A</u> <u>IR GGE custom 1618132</u>
	 International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at <u>https://data.imf.org</u> International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at https://www.imf.org/en/Publications/WEO/weo-
	database/2021/October

V1Suggested citation of this document: Kirchengast, G., and G. Thalassinos (2022), Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, University of Graz, Graz, Austria. Online at www.gcci.earth/austria/gem

GEM-AT Content and References

GEM-GHG Emissions Monitoring – Domain Austria

Version GCCIv1.2 Information Sheet on the GEM-AT Variables Tabular List of Variables & SubVariables together with explanations and data source references

How-to-Read Template: Format and content of the information per Variable in the Table below

VN. Variable N	<i>Explanation:</i> brief explanation of what Variable <i>N</i> expresses and optionally (e.g., in case of an index variable in units [%]) how it is computed				
[Unit]	<datasourceshortcite string="" vn=""> (as cited within the chart at the GCCI data portal)</datasourceshortcite>				
	SVN.1	<datesources string="" svn.1=""> (from GCCIv1 SV definitions file)</datesources>			
	Name	Reference(s) to the data source(s) for SVN.1, incl DOIs, Weblinks, etc, as available (one or more detailed references)			
	SVN.2 SubVariable <i>N</i> .2 Name	<datesources string="" svn.2=""> (from GCCIv1 SV definitions file)</datesources>			
		Reference(s) to the data source(s) for SVN.2, incl DOIs, Weblinks, etc, as available (one or more detailed references)			
	SVN.3	<datesources string="" svn.3=""> (from GCCIv1 SV definitions file)</datesources>			
	Name	Reference(s) to the data source(s) for SVN.3, incl DOIs, Weblinks, etc, as available (one or more detailed references)			
	SVN.4	<datesources string="" svn.4=""> (from GCCIv1 SV definitions file)</datesources>			
	Name	Reference(s) to the data source(s) for SVN.4, incl DOIs, Weblinks, etc, as available (one or more detailed references)			

GEM-AT Information Sheet Table: GEM-GHG Emissions Monitoring – Domain Austria

Variable (V) Name	SubVariable (SV) Name	Variable Explanation and Data Source References	
V1. CO2-based climate change (CC) mitigation index [%]	Explanation: The on annual CO ₂ e success of emiss average 1990-19 The SubVariable as well as the pre emission reduct or also including ("incl path2Paris (2020) at countre GEM-EUR) and se shares of the co Formula for the (based on the pre Index(Year i) [%] The main GCCI if indicates success neutrality) while The complement	is is one of the two primary index variables of GEM-AT, the one based missions of Austria and its nine states since 1990. It indicates the sion reductions in any given year as a percentage against the annual- 094 CO ₂ emissions ("Em(Year <i>i</i>)" vs "AvgEm(1990-1994)"). es include the main GCCI climate change mitigation index (SVs 1.1&1.2) roduction-based (SVs 1.3&1.5) and consumption-based (SVs 1.4&1.6) ion indices, respectively, either up to the latest year with data (first SVs) g a reduction scenario to 2050 compliant with the Paris climate goals s" SVs). The scenario path data are after Kirchengast and Steininger ry level (except for SV1.6 for which the path is modeled as explained in scaled for the state level paths in proportion to the state's emission untry-total emissions in year 2019. GCCI climate change mitigation index gauging emission reductions: roduction-based emission data) I = 100 x [Em(Year <i>i</i>) / AvgEm(1990-1994) – 1] production- and consumption-based emission reduction indices:] = 100 x [Em(Year <i>i</i>) / AvgEm(1990-1994)] ndex hence expresses the level of reductions against 0% near 1990. It s for achieving percentage values below 0% towards –100% (climate e it indicates failure by values that stick above 0% or even increase. tary two indices rather gauge the changes against 100% near 1990.	
	WEGC-GCCI 2021 & GCP-EmDB 2020 & UBA-EmDB 2021		
SV1.1 GCCI CC mitigation index CO2 emission reduction (goal -100% vs 1990-94=0%)	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/austria/gem</u> (see under "Explanation" above on the index computation) 		
	SV1.2 GCCLCC	WEGC-GCCI/Kirc-etal 2021 (incl GCCI v1 ATwide&StateEPC-scen)	
	mitigation index CO2 emission reduction incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/austria/gem Kirchengast and Steininger (2020). Treibhausgasbudget für Österreich auf dem Weg zur Klimaneutralität 2040 (in German). Wegener Center Statement 9.10.2020, Online at www.wegcenter.at/downloads/2020 	
	SV1.3 Production-	WEGC-GCCI/Kirc-etal 2021 & UBA-EmDB 2021	
	based CO2 emission reduction index	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/austria/gem</u> (see under "Explanation" above on the index computation) 	

		 Environment Agency Austria (Umweltbundesamt-UBA) (2021). Austria's National Inventory Report 2021. Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u>
S C b r r ir ir	SV1.4	WEGC-GCCI/Kirc-etal 2021 & UBA-EmDB 2021 & GCP-EmDB 2020
	based CO2 emission reduction index	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/austria/gem</u> (see under "Explanation" above on the index computation)
		 Environment Agency Austria (Umweltbundesamt-UBA) (2021). Austria's National Inventory Report 2021. Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u>
		 Friedlingstein et al. (2020). <i>Global Carbon Budget 2020</i>. Earth Syst. Sci. Data, 12, 3269–3340. Online at <u>https://doi.org/10.5194/essd-12-3269-2020</u>
	SV1.5 Production-	WEGC-GCCI/Kirc-etal 2021 (incl GCCIv1 ATwide&StateEPC-scen)
Proc base emis redu inde path	based CO2 emission reduction index incl	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/austria/gem</u>
	path2Paris	 Kirchengast and Steininger (2020). Treibhausgasbudget für Österreich auf dem Weg zur Klimaneutralität 2040 (in German). Wegener Center Statement 9.10.2020, Online at <u>www.wegcenter.at/downloads/2020</u>
	SV1.6	WEGC-GCCI/Kirc-etal 2021 (incl GCCIv1 ATwide&StateEPC-scen)
	based CO2 emission reduction index incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/austria/gem Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ, Change in rev. (until online, available on request)
V2. GHG-based climate change (CC) mitigation index [%]	Explanation: See SubVariables of the annual gree rather than on t GHGs according measured in Mil	e the explanation at the beginning of the Variable V1 block above—the this Variable V2 are constructed in exactly the same way but based on nhouse gas (GHG) emissions of Austria and its nine states since 1990 he CO ₂ emissions only. The GHG emissions include all climate-relevant to international accounting principles (also CH ₄ , N ₂ O, etc.) and are lion tons of CO ₂ equivalent [MtCO ₂ eq] (see under Variable V4 below).
	WEGC-GCCI 202	1 & UBA-AT EmDB & WEGC-EC 2020
	SV2.1 GCCI CC	WEGC-GCCI/Kirc-etal 2021
	mitigation index GHG	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet

	emission reduction (goal -100% vs 1990-94=0%)	<i>GEM-AT</i> . DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/austria/gem</u> (see under "Explanation" above on the index computation)
	SV2.2 GCCI CC	WEGC-GCCI/Kirc-etal 2021 (incl GCClv1 ATwide&StateEPC-scen)
	mitigation index GHG emission reduction incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/austria/gem Kirchengast and Steininger (2020). Treibhausgasbudget für Österreich auf dem Weg zur Klimaneutralität 2040 (in German). Wegener Center Statement 9.10.2020, Online at www.wegcenter.at/downloads/2020
	SV2.3 Production-	WEGC-GCCI/Kirc-etal 2021 & UBA-AT EmDB 2020
	Production- based GHG emission reduction index	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/austria/gem</u> (see under "Explanation" above on the index computation)
		 Environment Agency Austria (Umweltbundesamt-UBA) (2021). Austria's National Inventory Report 2021. Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u>
	SV2.4 Consumption- based GHG emission reduction index	WEGC-GCCI/Kirc-etal 2021 & UBA-AT EmDB 2021 & WEGC-EC 2020
		 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/austria/gem</u> (see under "Explanation" above on the index computation)
		 Environment Agency Austria (Umweltbundesamt-UBA) (2021). Austria's National Inventory Report 2021. Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u>
		 Nabernegg and Steininger-EconClim (2020). Austria's consumption-based emissions updated from Steininger et al. (2018) Austria's consumption-based greenhouse gas emissions. Global Environ. Change, 48, 226-242. Online at https://doi.org/10.1016/j.gloenvcha.2017.11.011
	SV2.5 Production- based GHG emissions incl path2Paris	WEGC-GCCI/Kirc-etal 2021 (incl GCClv1 ATwide&StateEPC-scen)
		 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/austria/gem</u>
		 Kirchengast and Steininger (2020). Treibhausgasbudget für Österreich auf dem Weg zur Klimaneutralität 2040 (in German). Wegener Center Statement 9.10.2020. Online at www.wegcenter.at/downloads/2020

SV Cu ba ei pa	SV2.6 Consumption-	WEGC-GCCI/Kirc-etal 2021 (incl GCCIv1 ATwide&StateEPC-scen)
	based GHG emissions incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/austria/gem</u> Kirchengast (2021). Simple hudget-based linear & floor emission
		reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
	_	
V3. CO2 annual emissions [MtCO ₂]	Explanation: The the one based of country-total properties the SubVariable 3.2&3.4) annual latest year with with the Paris clear Kirchengast and is modeled as explosed to the state's endoted to the state of the	is is one of the two primary amount-of-emissions variables of GEM-AT, n annual CO_2 emissions of Austria and its nine states since 1990 (except oduction-based CO_2 emissions being available from 1960). Is include production-based (SVs 3.1&3.3) and consumption-based (SVs emissions measured in Million tons of CO_2 [MtCO ₂], either up to the data (first SVs) or also including a reduction scenario to 2050 compliant imate goals ("incl path2Paris" SVs). The scenario path data are after Steininger (2020) at country level (except for SV3.4 for which the path explained in GEM-EUR) and scaled for the state level paths in proportion hission shares of the country-total emissions in year 2019.
	GCP-GlobCarbPr	oj & UBA-AT EmDB & WEGC 2021
	SV3.1 Production-	UBA-AT EmDB 2021 / WEGCupd 2021
	based CO2 emissions	 Environment Agency Austria (Onweitbundesamt-OBA) (2021). Austria's National Inventory Report 2021. Reports on the Austrian Air Pollution Inventory (OLI). Online at https://www.umweltbundesamt.at/emiberichte
	SV3.2	UBA-AT EmDB 2021 & GCP-EmDB 2020 / WEGCupd 2021
	emissions	 Environment Agency Austria (Umweltbundesamt-UBA) (2021). <i>Austria's National Inventory Report 2021</i>. Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u> Friedlingstein et al. (2020). <i>Global Carbon Budget 2020</i>. Earth Syst. Sci. Data, 12, 3269–3340. Online at <u>https://doi.org/10.5194/essd-12-3269-2020</u>
	SV3.3 Production	WEGC/Kirc-etal 2021 (inclGCClv1 ATwide&StateEPC-scen)
	based CO2 emissions incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/austria/gem (see also the reference under SubVariable SV3.1 above) Kirchengast and Steininger (2020). Treibhausgasbudget für Österreich auf dem Weg zur Klimaneutralität 2040 (in German). Wegener Center Statement 9.10.2020. Online at www.wogcoptor at/downloads/2020
		WEGC/Kirc-etal 2021 (incl GCClv1 ATwide&StateEPC-scen)

	SV3.4 Consumption- based CO2 emissions incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/austria/gem</u> (see also the references under SubVariable SV3.2 above) Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request) 	
V4. GHG annual emissions [MtCO₂eq]	Explanation: See SubVariables of the annual gree rather than on t GHGs according measured in Mil Compared to Va here for GHGs: t which means to Change, and For net sink, which i	e the explanation at the beginning of the Variable V3 block above—the this Variable V4 are constructed in exactly the same way but based on nhouse gas (GHG) emissions of Austria and its nine states since 1990 he CO ₂ emissions only. The GHG emissions include all climate-relevant to international accounting principles (also CH ₄ , N ₂ O, etc.) and are llion tons of CO ₂ equivalent [MtCO ₂ eq]. ariable V3, one additional amount-of-emissions SubVariable is available the production-based GHG emissions including from land use change, also count in the annual net emissions from Land Use, Land Use restry (LULUCF). These are negative in case the LULUCF sector acts as is the case for Austria (i.e., SV4.2 emissions lower than those of SV4.1).	
	UBA-AT EmissionsDB & WEGC 2021		
	SV4.1 Production- based GHG emissions	 UBA-AT EmDB 2020 / WEGCupd 2021 Environment Agency Austria (Umweltbundesamt-UBA) (2021). Austria's National Inventory Report 2021. Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u> 	
	SV4.2	UBA-AT EmDB 2020 / WEGCupd 2021	
	Production- based GHG emissions incl from Land use change	 Environment Agency Austria (Umweltbundesamt-UBA) (2021). Austria's National Inventory Report 2021. Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u> 	
	SV4.3	UBA-AT EmDB & WEGC-EconClim 2020 / WEGCupd 2021	
	consumption- based GHG emissions	 Environment Agency Austria (Umweltbundesamt-UBA) (2021). <i>Austria's National Inventory Report 2021</i>. Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u> Nabernegg and Steininger-EconClim (2020). Austria's consumption-based emissions updated from Steininger et al. (2018) <i>Austria's consumption-based greenhouse gas emissions</i>. Global Environ. Change, 48, 226-242. Online at <u>https://doi.org/10.1016/j.gloenvcha.2017.11.011</u> 	
	SV4.4 Production	WEGC/Kirc-etal 2021 (incl GCCl v1 ATwide&StateEPC-scen)	
	based GHG emissions incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/austria/gem</u> 	

	SV4.5 Consumption- based GHG emissions incl path2Paris	 (see also the reference under SubVariable SV4.1 above) Kirchengast and Steininger (2020). <i>Treibhausgasbudget für</i> <i>Österreich auf dem Weg zur Klimaneutralität 2040 (in German).</i> Wegener Center Statement 9.10.2020. Online at <u>www.wegcenter.at/downloads/2020</u> WEGC/Kirc-etal 2021 (incl GCCI v1 ATwide&StateEPC-scen) Kirchengast and Kohlfürst (2021). <i>Graz Climate Change Indicators</i> <i>(GCCI) Content and References Information Sheets—InfoSheet</i> <i>GEM-AT.</i> DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/austria/gem</u> (see also the references under SubVariable SV4.3 above) Kirchengast (2021). <i>Simple budget-based linear & floor emission</i> <i>reduction path modeling</i> following Williges et al. (2021) <i>Fairness</i> <i>critically conditions the carbon budget allocation across countries.</i> Global Environ. Change in rev. (until online, available on request) 	
V5. CO2 annual emissions per person [tCO ₂ /Person]	Explanation: The of GEM-AT, the 1990 (except co from 1960). The of-emissions dat its nine states (V The SubVariable 5.2&5.4) annual [tCO ₂ /Person], ereduction scena SVs). The releval Steininger (2020) explained in GEI emission shares Variable V3, just Variable V7).	is is one of the two primary amount-of-emissions-per-person variables one based on annual CO_2 emissions of Austria and its nine states since untry-total production-based CO_2 emissions per person being available per-person data of this variable are derived from dividing the amount- ta of Variable V3 by the respective population size data of Austria and Variable V7 below). Is include production-based (SVs 5.1&5.3) and consumption-based (SVs emissions per person measured in tons of CO_2 per person of the up to the latest year with data (first SVs) or also including a rio to 2050 compliant with the Paris climate goals ("incl path2Paris" nt amount-of-emission scenario path data are after Kirchengast and b) at country level (except for SV5.4 for which the path is modeled as M-EUR) and scaled for the state level paths in proportion to the state's of the country-total emissions in year 2019 (i.e., same data as for it divided by the respective scenario-based population size data of	
	UBA/GCP-EmDBs & STA/UN-PopDBs 2020 & WEGC 2021		
	SV5.1	UBA-AT EmDB 2021 & STATA-AT PopDB 2020 / WEGCupd 2021	
	Production- based CO2 emissions per Person	 Environment Agency Austria (Umweltbundesamt-UBA) (2021). <i>Austria's National Inventory Report 2021</i>. Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u> Statistics Austria (2020). <i>Total Population 1.1.2021</i>. Online at <u>https://www.statistik.at/web_en/statistics/PeopleSociety/populat_ion/index.html</u> 	
	SV5.2	UBA-AT/GCP EmDBs & STATA-AT PopDB 2020 / WEGCupd 2021	
	Consumption- based CO2 emissions per Person	 Environment Agency Austria (Umweltbundesamt-UBA) (2021). <i>Austria's National Inventory Report 2021</i>. Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u> Friedlingstein et al. (2020). <i>Global Carbon Budget 2020</i>. Earth Syst. Sci. Data, 12, 3269–3340. Online at 	

		- https://doi.org/10.5194/essd-12-3269-2020
		– Statistics Austria (2020). Total Population 1.1.2021. Online at
		https://www.statistik.at/web_en/statistics/PeopleSociety/populat
		<u>ion/index.html</u>
	SV5.3 Production-	WEGC/Kirc-etal 2021 & UN PopDB (incl GCClv1 ATw&StateEPC-scen)
	based CO2 emissions per Person incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/austria/gem</u> (see also the references under SubVariable SV5.1 above)
		 Kirchengast and Steininger (2020). Treibhausgasbudget für Österreich auf dem Weg zur Klimaneutralität 2040 (in German). Wegener Center Statement 9.10.2020. Online at www.wegcenter.at/downloads/2020
		 United Nations (UN) (2020). <i>Population Dynamics</i>. Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u>
	SV5.4	WEGC/Kirc-etal 2021 & UN PopDB (incl GCClv1 ATw&StateEPC-scen)
	based CO2 emissions per Person incl path2Paris	 Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/austria/gem</u> (see also the references under SubVariable SV5.2 above)
		 Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request)
		 United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u>
V6. GHG annual emissions per person [tCO ₂ eq/Person]	Explanation: See SubVariables of the annual green rather than on t GHGs according per-person basis Compared to Va is available here from land use ch Land Use, Land I LULUCF sector a person lower the	e the explanation at the beginning of the Variable V5 block above—the this Variable V5 are constructed in exactly the same way but based on nhouse gas (GHG) emissions of Austria and its nine states since 1990 he CO ₂ emissions only. The GHG emissions include all climate-relevant to international accounting principles (also CH ₄ , N ₂ O, etc.) and are, on a s, measured in tons of CO ₂ equivalent per person [tCO ₂ eq/Person]. riable V5, one additional amount-of-emissions-per-person SubVariable for GHGs: the production-based GHG emissions per person including nange, which means to also count in the annual net emissions from Use Change, and Forestry (LULUCF). These are negative in case the cts as net sink, which is the case for Austria (i.e., SV6.2 emissions per an those of SV6.1).
	UBA-AT EmDB &	sTA/UN-PopDBs & WEGC 2021
	SV6.1 Production- based GHG	UBA-AT EmDB & STATA-PopDB 2020 / WEGCupd 2021
		 Environment Agency Austria (Umwelbundesamt-UBA) (2021). Austria's National Inventory Report 2021. Reports on the

emissions per Person SV6.2 Production- based GHG	 Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u> Statistics Austria (2020). <i>Total Population 1.1.2021</i>. Online at <u>https://www.statistik.at/web_en/statistics/PeopleSociety/populat</u> <u>ion/index.html</u> UBA-AT EmDB & STATA-PopDB 2020 / WEGCupd 2021 Environment Agency Austria (Umwelbundesamt-UBA) (2021).
emissions per Person incl from Land use change	 Austria's National Inventory Report 2021. Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u> Statistics Austria (2020). Total Population 1.1.2021. Online at <u>https://www.statistik.at/web_en/statistics/PeopleSociety/populat</u> ion/index.html
SV6.3 Consumption- based GHG emissions per Person	 UBA-AT EmDB & STATA-PopDB & WEGC-EC 2020 / WEGCupd 2021 Environment Agency Austria (Umwelbundesamt-UBA) (2021). Austria's National Inventory Report 2021. Reports on the Austrian Air Pollution Inventory (OLI). Online at https://www.umweltbundesamt.at/emiberichte Statistics Austria (2020). Total Population 1.1.2021. Online at https://www.statistik.at/web_en/statistics/PeopleSociety/populat ion/index.html Nabernegg and Steininger-EconClim (2020). Austria's consumption-based emissions updated from Steininger et al. (2018) Austria's consumption-based greenhouse gas emissions. Global Environ. Change, 48, 226-242. Online at https://doi.org/10.1016/j.gloenvcha.2017.11.011
SV6.4 Production- based GHG emissions per Person incl path2Paris	 WEGC/Kirc-etal 2021 & UN-PopDB (incl GCCIv1 ATw&StateEPC-scen) Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCCIv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/austria/gem (see also the references under SubVariable SV6.1 above) Kirchengast and Steininger (2020). Treibhausgasbudget für Österreich auf dem Weg zur Klimaneutralität 2040 (in German). Wegener Center Statement 9.10.2020. Online at www.wegcenter.at/downloads/2020 United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at https://population.un.org/wpp/Download/Standard/Population/
SV6.5 Consumption- based GHG emissions per Person incl path2Paris	 WEGC/Kirc-etal 2021 & UN-PopDB (incl GCClv1 ATw&StateEPC-scen) Kirchengast and Kohlfürst (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet GEM-AT. DocID GCClv1.2-GEM-AT-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/austria/gem (see also the references under SubVariable SV6.3 above) Kirchengast (2021). Simple budget-based linear & floor emission reduction path modeling following Williges et al. (2021) Fairness

V7. Population size [No. of Persons]	<i>Explanation:</i> Th and its nine stat counted as [No. While the annua regular populati based data out t using the "medi about 7.7 to 9.7 from about 8.9 t	 critically conditions the carbon budget allocation across countries. Global Environ. Change in rev. (until online, available on request) United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at https://population.un.org/wpp/Download/Standard/Population/
	STAT-AT & UN P	opDBs 2020 & WEGCupd 2021
	SV7.1	STATA PopDB & UN PopDB 2020 / WEGCupd 2021
	Past-to- present population size	 Statistics Austria (2020). <i>Total Population 1.1.2021</i>. Online at https://www.statistik.at/web_en/statistics/PeopleSociety/population/index.html United Nations (UN) (2020). <i>Population Dynamics</i>. Department of Economic and Social Affairs. Online at https://population.un.org/wpp/Download/Standard/Population/
	SV7.2	UN PopDB 2020 / WEGCupd 2021
	scenario- based population size	 United Nations (UN) (2020). Population Dynamics. Department of Economic and Social Affairs. Online at <u>https://population.un.org/wpp/Download/Standard/Population/</u>
V8. Economic data [Billions of EUR]	Explanation: This auxiliary variable provides economic indicators since 1999 in its two subvariables. Both of these are inflation-adjusted which is marked by the word real. SV8.1 describes the real gross domestic product (GDP) or on regional level the gross regional domestic product, which is the value of all goods and services produced or exerted within a country's or region's borders. SV8.2 shows real purchasing power parity (PPP), which is GDP in terms of an exchange rate between countries that accounts for the value of a fixed basket of goods rather than the market exchange rates. In this manner it is less volatile than the market exchange rate. Both quantities are given in Euros (EUR).	
	IMF/WEO-DB &	STATA EconDB 2021/WEGCupd 2021
	SV8.1 Gross Domestic Product (real GDP)	 IMF/WEO-DB & STATA EconDB 2021/WEGCupd 2021 Statistics Austria (2021). Regional gross domestic product. Online at https://www.statistik.at/web_de/statistiken/wirtschaft/volkswirt_schaftliche_gesamtrechnungen/regionale_gesamtrechnungen/nu_ts2-regionales_bip_und_hauptaggregate/index.html International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at https://data.imf.org

	SV8.2 Purchasing Power Parity (real PPP)	 International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo- database/2021/October</u> IMF/WEO-DB & STATA EconDB 2021/WEGCupd 2021 Statistics Austria (2021). Regional gross domestic product. Online at <u>https://www.statistik.at/web_de/statistiken/wirtschaft/volkswirt</u> schaftliche gesamtrechnungen/regionale gesamtrechnungen/nu ts2-regionales bip_und_hauptaggregate/index.html International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at <u>https://data.imf.org</u> International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at https://www.imf.org/en/Publications/WEO/weo- database/2021/October
V9. Example 2 Constraints of the person of t	Explanation: The the same data a V7. This makes of Euros per person per person. IMF/WEO-DB & SV9.1 Gross Domestic Product (real GDP) per Person	 is diagnostic variable shows economic data on a per capita basis. It uses s described in Variable V8 divided by the population data in Variable data between countries easier to compare. The values are given in n (EUR per person). SV9.1 shows GDP per person and SV9.2 shows PPP STA EcDB&PDB 2021 & WEGCupd 2021 IMF/WEO-DB & STA EconDB&PopDB 2021/WEGCupd 2021 IMF/WEO-DB & STA EconDB&PopDB 2021/WEGCupd 2021 International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at <u>https://data.imf.org</u> International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns. Supply
		 Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo- database/2021/October</u> Statistics Austria (2020). Total Population 1.1.2021. Online at <u>https://www.statistik.at/web_en/statistics/PeopleSociety/popula</u> <u>tion/index.html</u> Statistics Austria (2021). Regional gross domestic product. Online at <u>https://www.statistik.at/web_de/statistiken/wirtschaft/volkswirt</u> schaftliche_gesamtrechnungen/regionale_gesamtrechnungen/nu <u>ts2-regionales_bip_und_hauptaggregate/index.html</u>
	SV9.2	IMF/WEO-DB & STA EconDB&PopDB 2021/WEGCupd 2021
Purch Powe (real Perso	Purchasing Power Parity (real PPP) per Person	 International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at <u>https://data.imf.org</u> International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund,

		 Publication Services. Online at https://www.imf.org/en/Publications/WEO/weo- database/2021/October Statistics Austria (2020). Total Population 1.1.2021. Online at https://www.statistik.at/web_en/statistics/PeopleSociety/popula tion/index.html Statistics Austria (2021). Regional gross domestic product. Online at https://www.statistik.at/web_de/statistiken/wirtschaft/volkswirt schaftliche_gesamtrechnungen/regionale_gesamtrechnungen/nu ts2-regionales_bip_und_hauptaggregate/index.html 	
V10. CO2 emissions per GDP and PPP [Tonnes of CO2 per Million EUR]	<i>Explanation:</i> The economy. Here PPP data to show PPP are measure emission calculation include production	is variable is one of two variables in GCCI that compares emissions and the CO2 emission data from Variable V3 are divided by the GDP and w how economy and emissions are related. CO2 emissions per GDP and ed in tonnes of CO2 per million Euro (tCO2pMEUR). Details on the tions can be read in the description of V3. The four subvariables ion- and consumption-based emissions per GDP and PPP, respectively.	
	UBA Em & IMF/WEO & STA Ec DB 2021 & WEGCupd 2021		
	SV10.1 Production-	UBA Em & IMF/WEO & STA Ec DB 2021 & WEGCupd 2021	
	based CO2 emissions per GDP	 Environment Agency Austria (Umweltbundesamt-UBA) (2021). <i>Austria's National Inventory Report 2021.</i> Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u> International Monetary Fund (IMF) (2021). <i>Exchange rates incl.</i> <i>Effective exchange rates.</i> Online at <u>https://data.imf.org</u> International Monetary Fund (IMF) (2021). <i>World Economic</i> <i>Outlook: Recovery during a Pandemic—Health Concerns, Supply</i> <i>Disruptions, Price Pressures.</i> International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo-</u> <u>database/2021/October</u> Statistics Austria (2021). <i>Regional gross domestic product.</i> Online at <u>https://www.statistik.at/web_de/statistiken/wirtschaft/volkswirt</u> <u>schaftliche_gesamtrechnungen/regionale_gesamtrechnungen/nu</u> <u>ts2-regionales_bip_und_hauptaggregate/index.html</u> 	
		UBA Em & IMF/WEO & STA Ec DB 2021 & WEGCupd 2021	

SV10.2 Consumption- based CO2 emissions per GDP	 Environment Agency Austria (Umweltbundesamt-UBA) (2021). Austria's National Inventory Report 2021. Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u> International Monetary Fund (IMF) (2021). Exchange rates incl. Effective exchange rates. Online at <u>https://data.imf.org</u> International Monetary Fund (IMF) (2021). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo- database/2021/October</u> Statistics Austria (2021). Regional gross domestic product. Online at <u>https://www.statistik.at/web_de/statistiken/wirtschaft/volkswirt schaftliche_gesamtrechnungen/regionale_gesamtrechnungen/nu ts2-regionales_bip_und_hauptaggregate/index.html</u>
SV10.3 Production-	UBA Em & IMF/WEO & STA Ec DB 2021 & WEGCupd 2021
based CO2 emissions per PPP	 Environment Agency Austria (Umweltbundesamt-UBA) (2021). <i>Austria's National Inventory Report 2021.</i> Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u> International Monetary Fund (IMF) (2021). <i>Exchange rates incl.</i> <i>Effective exchange rates.</i> Online at <u>https://data.imf.org</u> International Monetary Fund (IMF) (2021). <i>World Economic</i> <i>Outlook: Recovery during a Pandemic—Health Concerns, Supply</i> <i>Disruptions, Price Pressures.</i> International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo-</u> <u>database/2021/October</u> Statistics Austria (2021). <i>Regional gross domestic product.</i> Online at <u>https://www.statistik.at/web_de/statistiken/wirtschaft/volkswirt</u> <u>schaftliche_gesamtrechnungen/regionale_gesamtrechnungen/nu</u> <u>ts2-regionales_bip_und_hauptaggregate/index.html</u>
SV10.4 Consumption-	UBA Em & IMF/WEO & STA Ec DB 2021 & WEGCupd 2021
consumption- based CO2 emissions per PPP	 Environment Agency Austria (Umweltbundesamt-UBA) (2021). <i>Austria's National Inventory Report 2021.</i> Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u> International Monetary Fund (IMF) (2021). <i>Exchange rates incl.</i> <i>Effective exchange rates.</i> Online at <u>https://data.imf.org</u> International Monetary Fund (IMF) (2021). <i>World Economic</i> <i>Outlook: Recovery during a Pandemic—Health Concerns, Supply</i> <i>Disruptions, Price Pressures.</i> International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo-</u> <u>database/2021/October</u> Statistics Austria (2021). <i>Regional gross domestic product.</i> Online at <u>https://www.statistik.at/web.de/statistiken/wirtschaft/volkswirt</u>

		schaftliche gesamtrechnungen/regionale gesamtrechnungen/nu ts2-regionales_bip_und_hauptaggregate/index.html		
V11. GHG emissions per GDP and PPP [Tonnes of CO2 equivalent per Million EUR]	Explanation: The the same manner the emission call GDP and PPP are The four subvariant PPP, respectively and PPP, respectively a state of the four subvariant PPP.	is is the second emission-per-economy variable and it is calculated in er as Variable V10 but using GHG emissions from Variable V4. Details on culations can be read in the description of V4. The GHG emissions per e given in tonnes of CO2 equivalents per million Euro (tCO2eqpMEUR). iables include production- and consumption-based emissions per GDP tively.		
	UBA Em & IMF/			
	SV11.1 Production-	UBA Em & IMF/WEO & STA Ec DB 2021 & WEGCupd 2021		
	Production- based GHG emissions per GDP	 Environment Agency Austria (Umweltbundesamt-UBA) (2021). <i>Austria's National Inventory Report 2021</i>. Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u> International Monetary Fund (IMF) (2021). <i>Exchange rates incl.</i> <i>Effective exchange rates</i>. Online at <u>https://data.imf.org</u> International Monetary Fund (IMF) (2021). <i>World Economic</i> <i>Outlook: Recovery during a Pandemic—Health Concerns, Supply</i> <i>Disruptions, Price Pressures</i>. International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo-</u> <u>database/2021/October</u> Statistics Austria (2021). <i>Regional gross domestic product</i>. Online at <u>https://www.statistik.at/web_de/statistiken/wirtschaft/volkswirt</u> <u>schaftliche_gesamtrechnungen/regionale_gesamtrechnungen/nu</u> <u>ts2-regionales_bip_und_hauptaggregate/index.html</u> 		
	SV11.2	UBA Em & IMF/WEO & STA Ec DB 2021 & WEGCupd 2021		
	GDP	 Environment Agency Austria (Umweltbundesamt-UBA) (2021). <i>Austria's National Inventory Report 2021</i>. Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u> International Monetary Fund (IMF) (2021). <i>Exchange rates incl.</i> <i>Effective exchange rates</i>. Online at <u>https://data.imf.org</u> International Monetary Fund (IMF) (2021). <i>World Economic</i> <i>Outlook: Recovery during a Pandemic—Health Concerns, Supply</i> <i>Disruptions, Price Pressures</i>. International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo-</u> <u>database/2021/October</u> Statistics Austria (2021). <i>Regional gross domestic product</i>. Online at <u>https://www.statistik.at/web_de/statistiken/wirtschaft/volkswirt</u> <u>schaftliche_gesamtrechnungen/regionale_gesamtrechnungen/nu</u> <u>ts2-regionales_bip_und_hauptaggregate/index.html</u> 		
	SV11.3 Production-	UBA Em & IMF/WEO & STA Ec DB 2021 & WEGCupd 2021		

based GHG emissions per PPP	_	Environment Agency Austria (Umweltbundesamt-UBA) (2021). <i>Austria's National Inventory Report 2021.</i> Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u> International Monetary Fund (IMF) (2021). <i>Exchange rates incl.</i> <i>Effective exchange rates.</i> Online at <u>https://data.imf.org</u> International Monetary Fund (IMF) (2021). <i>World Economic</i> <i>Outlook: Recovery during a Pandemic—Health Concerns, Supply</i> <i>Disruptions, Price Pressures.</i> International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo-</u> <u>database/2021/October</u> Statistics Austria (2021). <i>Regional gross domestic product.</i> Online at <u>https://www.statistik.at/web_de/statistiken/wirtschaft/volkswirt</u> schaftliche_gesamtrechnungen/regionale_gesamtrechnungen/nu ts2-regionales_bip_und_hauptaggregate/index.html
SV11.4 Consumption-	UBA	A Em & IMF/WEO & STA Ec DB 2021 & WEGCupd 2021
based GHG emissions per PPP	-	Environment Agency Austria (Umweltbundesamt-UBA) (2021). <i>Austria's National Inventory Report 2021</i> . Reports on the Austrian Air Pollution Inventory (OLI). Online at <u>https://www.umweltbundesamt.at/emiberichte</u> International Monetary Fund (IMF) (2021). <i>Exchange rates incl.</i> <i>Effective exchange rates</i> . Online at <u>https://data.imf.org</u> International Monetary Fund (IMF) (2021). <i>World Economic</i> <i>Outlook: Recovery during a Pandemic—Health Concerns, Supply</i> <i>Disruptions, Price Pressures</i> . International Monetary Fund, Publication Services. Online at <u>https://www.imf.org/en/Publications/WEO/weo-</u> <u>database/2021/October</u> Statistics Austria (2021). <i>Regional gross domestic product</i> . Online at <u>https://www.statistik.at/web_de/statistiken/wirtschaft/volkswirt</u> schaftliche_gesamtrechnungen/regionale_gesamtrechnungen/nu ts2-regionales_bip_und_hauptaggregate/index.html

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CWM-GLO Content and References

CWM-Climate Warming Monitoring – Domain Global

Version GCCIv1.2 Information Sheet on the CWM-GLO Variables Tabular List of Variables & SubVariables together with brief explanations and data source references

VN Variable N Name [Unit]	Explanation : brief explanation of what Variable N expresses and optionally (e.g., in case of an index variable in units [%]) how it is computed		
	<datasourceshortcite string="" vn=""> (as cited within the chart at the GCCI data portal)</datasourceshortcite>		
	SVN.1 SubVariable N 1	<datesources string="" svn.1=""> (from GCClv1 SV definitions file)</datesources>	
	Name	Reference(s) to the data source(s) for SVN.1, incl DOIs, Weblinks, etc, as available (one or more detailed references)	
	SVN.2 SubVariable N 2	<datesources string="" svn.2=""> (from GCClv1 SV definitions file)</datesources>	
	Name	Reference(s) to the data source(s) for SVN.2, incl DOIs, Weblinks, etc, as available (one or more detailed references)	
	SVN.3 SubVariable <i>N</i> .3 Name	<datesources string="" svn.3=""> (from GCClv1 SV definitions file)</datesources>	
		Reference(s) to the data source(s) for SVN.3, incl DOIs, Weblinks, etc, as available (one or more detailed references)	
	SVN.4 SubVariable N.4	<datesources string="" svn.4=""> (from GCClv1 SV definitions file)</datesources>	
	Name	Reference(s) to the data source(s) for SVN.4, incl DOIs, Weblinks, etc, as available (one or more detailed references)	

How-to-Read Template: Format and content of the information per Variable in the Table below

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CWM-GLO Information Sheet Table: CWM-Climate Warming Monitoring – Domain Global

Variable (V) Name	SubVariable (SV) Name	Variable Explanation and Data Source References	
V1. AHC-based global warming index [%]	Explanation: This is of Atmospheric Heat Co anthropogenic global gases (GHGs) as show physical explanation of al. (2021b), Section 2. The index indicates, a how the decadal incre changed since around rate" of any center ye annual observations of The SubVariables incl for informing on the a 1980-2000 that amou for comparison, the w Formula for the GCCI (based on the AHC de Index(CtrYear i) [%] = The index hence expr 1990. It indicates stro	ne of the two primary index variables of CWM-GLO, the one based on global ntent (AHC) increase rates since around 1990. This increase is mainly due to warming caused by the continued emission of CO ₂ and other greenhouse on in GEM-GLO for the global emissions and countries worldwide. For a brief of why and how this global warming unfolds see, for example, Kirchengast et 1 therein (cited under SV1.1 below). s a percentage against the average 1980-2000 AHC decadal increase rate, ease rate of heat energy in the atmosphere in any given center year has d 1990 ("Rate(CtrYear <i>i</i>)" vs "AvgRate(1980-2000)"). The "decadal increase ear is computed as decadally smoothed (center year ± 5 years)-linearfit to the of AHC gain since 1960 (shown as SubVariable SV4.6 of Variable V4). ude the GCCI global warming index (SV1.1) as well as, just as a reference and absolute reference value, the 100%-baseline average AHC increase over inted to 0.48 ZJ/decade (SV2.2) (1ZJ = 10^{21} J = 1 trillion gigajoules of energy; vorld's total annual energy consumption is about 0.6 ZJ). global warming index gauging atmospheric heat energy increase: cadal increase rate data shown in Variable V2) 100 x [Rate(CtrYear <i>i</i>)/AvgRate(1980-2000)] esses how strongly the AHC increase rate changed against 100% around ong heat accumulation due to global warming if percentages raise high above	
	100%, like in the most recent decade (center year 2015) where over 500% indicate an over fold increase (to over 2.5 ZJ/decade), while values within 100±200% may occur from natur variability. Natural inter-annual to decadal AHC variations from atmosphere-ocean variability including effects from El Niño Southern Oscillation (ENSO), from the Pacific Decadal Oscilla (PDO), Indian Ocean Dipole (IOD), and the Atlantic Meridional Overturning Circulation (AN may be subtracted in a follow-on version, which may further improve the index focus on to long-term anthropogenic warming. <i>Related advance info:</i> GCCIv1 does not yet optionally include AHC increase predictions to and projections to 2050; these are under development and will be included in follow-on version.		
	WEGC Kircetal & ERA	5-JRA55-MERRA2-RADSrc 2021	
	GCCI global warming index Atmospheric Heat Content (AHC) increase	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/cwm (see under "Explanation" above on the index computation) Kirchengast et al. (2021b). Carbon Management: A new approach to achieve Paris-compliant climate goals. WEGC Research Briefs 1-2021, Wegener Center Verlag, Univ. of Graz, Austria. Online at https://doi.org/10.25364/23.2021.1 (Section 2.1 at https://unipub.uni- graz.at/obvugrveroeff/content/pageview/6047842) 	
	SV1.2	WEGC-GCCI/Kircetal 2021 (bgr data WEGC CWM-DB & ERA-JRA-MERRA)	
	warming index Avg1980-2000 (100%=0.48 ZJ/decade)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the index computation) 	

V2. Atmospheric Heat Content (AHC) increase [ZJ/decade]	Explanation: This Var global Atmospheric H anthropogenic global gases (GHGs) as show physical explanation Section 2.1 therein; m The SubVariable inclu "decadal increase rat ± 5 years)-linearfit to of Variable V4). The r energy; for comparise from values within 0. ZJ/decade in the mos strong imprint of the variations from atmo (ENSO), from the Pac Meridional Overturni further improve the f <i>Related advance info</i> and projections to 20	riable V2 is the basis for the index variable V1 of CWM-GLO; it indicates the leat Content (AHC) increase since the 1960s. This increase is mainly due to warming caused by the continued emission of CO ₂ and other greenhouse win in GEM-GLO for the global emissions and countries worldwide. For a brief of why and how this global warming unfolds see Kirchengast et al. (2021b), nore details are available via Kirchengast et al. (2021c) (both cited below). uded is the AHC decadal increase rate since center year 1965 (SV2.1). This e" is computed for any given center year as decadally smoothed (center year the annual observations of AHC gain since 1960 (shown as SubVariable SV4.6 ates are shown in units [ZJ/decade] ($1ZJ = 10^{21}J = 1$ trillion gigajoules of on, the world's total annual energy consumption is about 0.6 ZJ). They reach 5 ± 1 ZJ/decade in the early decades (mainly natural variability) to over 2.5 tt recent decade (center year 2015, i.e., applying to 2010-2020), which is a recent anthropogenic global warming. Natural inter-annual to decadal AHC sphere-ocean variability including effects from El Niño Southern Oscillation ific Decadal Oscillation (PDO), Indian Ocean Dipole (IOD), and the Atlantic ng Circulation (AMOC) may be subtracted in a follow-on version, which may focus of the variable to monitor long-term anthropogenic warming. c GCClv1 does not yet optionally include AHC increase predictions to 2030 150; these are under development and will be included in follow-on versions.		
	WEGC Kircetal & ERA5-JRA55-MERRA2-RADSrc 2021			
	SV2.1	WEGC/Kircetal 2021 (bgr data WEGC CWM-DB & ERA-JRA-MERRA)		
Atr Cor inc (de	Atmospheric Heat Content (AHC) increase rate (decadal)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation) 		
		 Kirchengast et al. (2021b). Carbon Management: A new approach to achieve Paris-compliant climate goals. WEGC Research Briefs 1-2021, Wegener Center Verlag, Univ. of Graz, Austria. Online at <u>https://doi.org/10.25364/23.2021.1</u> (Section 2.1 at <u>https://unipub.uni- graz.at/obvugrveroeff/content/pageview/6047842</u>) 		
		 Kirchengast et al. (2021c). Section 3 on AHC in von Schuckmann et al. (2020) Heat stored in the Earth system: where does the energy go?. Earth Syst. Sci. Data, 12, 2013-2041 (online at https://essd.copernicus.org/articles/12/2013/2020/#section3) and Kirchengast et al. (2019-2021) Climate trends and variability in Atmospheric Heat Content and atmosphere-ocean heat exchanges etc. IUGG 2019 Conf. Invited Pres. Montreal CA (online https://www.czech-in.org/cmPortalV15/CM_W3_Searchable/iugg19/#!sessiondetails/0000119801_0), ICGPSRO 2020 Conf. Invited Pres. Hsinchu TW, Manuscript in prep. 2021 (online link added after publication) 		
V3. EEI-based climate change index [%]	Explanation: This is to on global Earth Energy and Radiative Respor- linked to a still widen the ongoing anthropo greenhouse gases (GI worldwide. For a brie climate forcing (ERF) consequently unfold.	he second of the two primary index variables of CWM-GLO, the one based sy Imbalance (EEI) increase and the related Effective Radiative Forcing (ERF) has Estimate (RRE) increases since around 1990. The EEI and its increase, ing gap between the ERF and (lagging) RRE increases, occur mainly due to ogenic climate change caused by the continued emission of CO ₂ and other HGs) as shown in GEM-GLO for the global emissions and countries if physical explanation of the fundamental significance of the EEI related to and climate response (RRE), and how global warming and climate change do see Kirchengast et al. (2021b). Section 2.1 therein: more details are		

T.		
available via von Schu The SubVariables inclu- well as the related ER (SV3.3), respectively. The main GCCI index in how the decadal incre- changed since around rate" of any center yea annual observations of Variable V4). Likewise percentage changes s respective decadal-mi- decadal-rate dataset of <i>Formula for the GCCI</i> (based on the EEI deco Index(CtrYear i) [%] = <i>Formula for the ERF-bi</i> (based on the ERF and Index(CtrYear i) [%] = The main GCCI index I indicates strong ongo the last two decades I basis, in absolute ene currently 0.6 ZJ/year). 100% (about 0.45 Wm shrinking again and ho global emission reduct to decadal EEI variatio Southern Oscillation ((IOD), and the Atlantio on version, which mar warming. <i>Related advance info:</i>	ilable via von Schuckmann et al. (2020) (both cited below). SubVariables include the main GCCI climate change index based on the EEI increase (SV3.1) as I as the related ERF-based climate forcing index (SV3.2) and RRE-based climate response index 3.3), respectively. main GCCI index indicates, as a percentage against the average 1988-1992 EEI decadal rates, v the decadal increase rate of energy uptake in the Earth system in any given center year has nged since around 1990 ("Rate(CtrYear i)" vs "AvgRate(1988-1992)"). The "decadal increase 2" of any center year is computed as five-year-smoothed (center year±5 years)-linearfit to the uial observations of total Earth energy uptake since 1960 (shown as SubVariable SV4.1 of iable V4). Likewise the climate forcing and response indices are computed in the same way as centage changes since around 1990 ("Value(CtrYear i)" vs "AvgRate(1988-1992)"), using the bective decadal-mean ERF and RRE datasets of Variable V11, which also contains the EEI adal-rate dataset used. mula for the EGCI climate change index gauging climate change strength via EEI increase: sed on the EEI decadal increase rate data of SV11.1 of Variable V11) ex(CtrYear i) [%] = 100 x [Rate(CtrYear i) / AvgRate(1988-1992)] mula for the ERF-based climate forcing and RRE-based climate response indices: sed on the ERF and RRE data of SV11.2 ond SV11.3 of Variable V11) ex(CtrYear i) [%] = 100 x [Value(CtrYear i) / AvgRate(1988-1992)] main GCCI index hence expresses in what way the EEI changed against 100% around 1990. It icates strong ongoing climate change if percentages are persistently higher than 100 %, like in last two decades higher than 150% (more than 11 ZJ/year, or 0.7 Wm ² on a per-square-meter is, in absolute energy uptake; for comparison, the world's total annual energy consumption is rently 0.6 ZJ/year). Conversely, if the index would decrease within the next decades to below 1% (about 0.45 Wm ²), and then further to below 50%, this would prove tha	
WEGC Kircetal & NOA	A-NASA-ECMWF&MiscSciSrc 2021	
SV3.1	WEGC Kircetal 2021 & vSchucketal 2020 & MiscSciSrc	
GCCI climate change index Earth Energy Imbalance (EEI) increase	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/cwm (see under "Explanation" above on the variables' computation; and see also the further references under Variable 11/SV11.1 below that contains the data underlying this index) Kirchengast et al. (2021b). Carbon Management: A new approach to achieve Paris-compliant climate goals. WEGC Research Briefs 1-2021, Wegener Center Verlag, Univ. of Graz, Austria. Online at https://doi.org/10.25364/23.2021.1 (Section 2 at https://unipub.uni- graz.at/obvugrveroeff/content/pageview/6047842) von Schuckmann et al. (2020). Heat stored in the Earth system: where does the energy go? Earth Syst. Sci. Data, 12, 2013-2041. Online at https://doi.org/10.5194/essd-12-2013-2020 	
SV3.2	WEGC Kircetal 2021 & NOAA & MiscSciSrc	

	Effective Radiative Forcing-based climate forcing index SV3.3 Radiative Response Estimate-based climate response index	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation; and see also the further references under Variable 11/SV11.2 below that contains the data underlying this index) WEGC Kircetal 2021 & NASA-ECMWF & MiscSciSrc Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation; and see also the further references under Variable 11/SV11.3 below that contains the data underlying this index) 	
V4. Earth energy uptake since 1960 [ZJ]	Explanation: This Variable is the Earth energy uptake variable of CWM-GLO, the one that sh how much energy the Earth system and its main components have accumulated over time is 1960 (in units [ZJ]; 1 ZJ = 10 ²¹ J = 1 trillion gigajoules; for an impression of size, the world's to annual energy consumption is currently about 0.6 ZJ). This long-term energy uptake over th recent decades occurs mainly due to the ongoing anthropogenic global warming caused by continued emission of CO ₂ and other greenhouse gases (GHGs) as shown in GEM-GLO for the global emissions and countries worldwide. For a brief physical explanation of the significance Earth's energy uptake and the associated Earth energy imbalance (EEI), and how global war and climate change do consequently unfold, see Kirchengast et al. (2021b), Section 2.1 ther more details are available via von Schuckmann et al. (2020) (both cited below). The SubVariables include the total global Earth energy uptake (SV4.1) as well as its contribut heat energy gain and energy uptake components from five main subsystems of the Earth sy ocean below uppermost layer (SV4.2), uppermost ocean (SV4.3), land (SV4.4), cryosphere (S and atmosphere (SV4.6). All are provided annually as accumulated gain or uptake since arou 1960 (i.e., vs. 1958-1962 average or 1960-1964 average, depending on data availability). The total energy uptake since 1960 was below 50 ZJ before 1990 but then strongly increased values of about 300 to 430 ZJ in the most recent decade, a growth of around 13 ZJ/year (see variable V5 below, which expresses the increase rate of this accumulated uptake). Comparit to the world's total annual energy consumption of currently 0.6 ZJ/year, this recent increase more than 20 times as large, mainly driven by the ongoing global warming. The accumulate gradually start to stop only if global warming starts slowing down thanks to the success of P coming the start of stop only if global warming starts slowing down thanks to the success of P coming the start of stop only if gl		
	WEGC Kircetal 2021 & vSchucketal 2020 & MiscSciSrc		
	SV4.1 Earth energy uptake (total Earth system) (vsAvg1960)	 WEGC Kircetal & CWM-DB 2021 & MiscDatSrc Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/cwm (see under "Explanation" above on the variables' computation and see also the further references under SV4.2 to SV4.6 below) Kirchengast et al. (2021c). Section 3 on AHC in von Schuckmann et al. (2020) Heat stored in the Earth system: where does the energy go?. Earth Syst. Sci. Data, 12, 2013-2041 (online at https://essd.copernicus.org/articles/12/2013/2020/#section3) and Kirchengast et al. (2019-2021) Climate trends and variability in Atmospheric Heat Content and atmosphere-ocean heat exchanges etc. 	

	IUGG 2019 Conf. Invited Pres. Montreal CA (online https://www.czech-
	in.org/cmPortalV15/CM W3 Searchable/iugg19/#!sessiondetails/ 0000119801 0), ICGPSRO 2020 Conf. Invited Pres. Hsinchu TW, Manuscript in prep. 2021 (online link added after publication)
	 von Schuckmann et al. (2020). Heat stored in the Earth system: where does the energy go? Earth Syst. Sci. Data, 12, 2013-2041. Online at https://doi.org/10.5194/essd-12-2013-2020
SV4.2	WEGC Kircetal 2021 & vSchucketal 2020 & IAP-ORAS5
Ocean neat content gain below UMOHC (depth>300m) (vsAvg1960)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCClv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation)
	 von Schuckmann et al. (2020). Heat stored in the Earth system: where does the energy go? Earth Syst. Sci. Data, 12, 2013-2041. Online at <u>https://doi.org/10.5194/essd-12-2013-2020</u>
	 Cheng et al. (2021). Upper ocean temperatures hit record high in 2020. Adv. Atmos. Sci., 38, 523-530. Online at <u>https://doi.org/10.1007/s00376-021-0447-x</u>
	 Zuo et al. (2019). The ECMWF operational ensemble reanalysis-analysis system for ocean and sea ice: a description of the system and assessment. Ocean Sci., 15, 779-808. Online at <u>https://doi.org/10.5194/os-15-779-2019</u>
SV4.3	WEGC Kircetal 2021 & vSchucketal 2020 & IAP-ORAS5
Heat Content (UMOHC) gain (depth 0-300m) (vsAvg1960)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation)
	 Kirchengast et al. (2021c). Section 3 on AHC in von Schuckmann et al. (2020) Heat stored in the Earth system: where does the energy go?. Earth Syst. Sci. Data, 12, 2013-2041 (online at https://essd.copernicus.org/articles/12/2013/2020/#section3) and Kirchengast et al. (2019-2021) Climate trends and variability in Atmospheric Heat Content and atmosphere-ocean heat exchanges etc. IUGG 2019 Conf. Invited Pres. Montreal CA (online https://www.czech-in.org/cmPortalV15/CM_W3_Searchable/iugg19/#lsessiondetails/0000119801_0), ICGPSRO 2020 Conf. Invited Pres. Hsinchu TW, Manuscript in prep. 2021 (online link added after publication)
	 von Schuckmann et al. (2020). Heat stored in the Earth system: where does the energy go? Earth Syst. Sci. Data, 12, 2013-2041. Online at <u>https://doi.org/10.5194/essd-12-2013-2020</u>
	 Cheng et al. (2021). Upper ocean temperatures hit record high in 2020. Adv. Atmos. Sci., 38, 523-530. Online at <u>https://doi.org/10.1007/s00376-021-0447-x</u>
	 Zuo et al. (2019). The ECMWF operational ensemble reanalysis-analysis system for ocean and sea ice: a description of the system and assessment. Ocean Sci., 15, 779-808. Online at <u>https://doi.org/10.5194/os-15-779-2019</u>

SV4.4 Land heat content gain (vsAvg1960)	vSchucketal 2020 / WEGCupd 2021	
	Land heat content gain (vsAvg1960)	 von Schuckmann et al. (2020). Heat stored in the Earth system: where does the energy go? Earth Syst. Sci. Data, 12, 2013-2041. Online at https://doi.org/10.5194/essd-12-2013-2020
	SV4.5	vSchucketal 2020 / WEGCupd 2021
	Cryospheric energy uptake (vsAvg1960)	 von Schuckmann et al. (2020). Heat stored in the Earth system: where does the energy go? Earth Syst. Sci. Data, 12, 2013-2041. Online at https://doi.org/10.5194/essd-12-2013-2020
	SV4.6	WEGC Kircetal & CWM-DB 2021 & ERA-JRA-MERRA
	Atmospheric Heat Content (AHC) gain (vsAvg1960)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation)
		 Kirchengast et al. (2021c). Section 3 on AHC in von Schuckmann et al. (2020) Heat stored in the Earth system: where does the energy go?. Earth Syst. Sci. Data, 12, 2013-2041 (online at https://essd.copernicus.org/articles/12/2013/2020/#section3) and Kirchengast et al. (2019-2021) Climate trends and variability in Atmospheric Heat Content and atmosphere-ocean heat exchanges etc. IUGG 2019 Conf. Invited Pres. Montreal CA (online https://www.czech-in.org/cmPortalV15/CM_W3_Searchable/iugg19/#!sessiondetails/0000119801_0), ICGPSRO 2020 Conf. Invited Pres. Hsinchu TW, Manuscript in prep. 2021 (online link added after publication)
		 Gelaro et al. (2017). The Modern-Era Retrospective Analysis for research and applications, Version 2 (MERRA-2). J. Clim., 30, 5419- 5454. Online at <u>https://doi.org/10.1175/jcli-d-16-0758.1</u>
		 Hersbach et al. (2020). <i>The ERA5 global reanalysis</i>. Q. J. Royal Met. Soc., 146, 1999-2049. Online at <u>https://doi.org/10.1002/qj.3803</u>
		 Japan Meteorological Agency (2013). JRA-55: Japanese 55-year reanalysis, monthly means and variance. Online at <u>https://doi.org/10.5065/D60G3H5B</u>
V5. Earth Energy Imbalance (EEI) [ZJ/year]	Explanation: This is one of the two Earth Energy Imbalance (EEI) variables of CWM-GLO, the one that provides the global EEI over time since the 1960s in units [ZJ/year] ($(1 \text{ ZJ} = 10^{21} \text{ J} = 1 \text{ trillion}$ gigajoules of energy; for comparison, the world's total annual energy consumption is currently about 0.6 ZJ). The EEI and its increase, linked to a still widening gap between climate forcing and response (see the Explanations under Variables V4 and V11), occur mainly due to the ongoing anthropogenic climate change caused by the continued emission of CO ₂ and other greenhouse gases (GHGs) as shown in GEM-GLO for the global emissions and countries worldwide. For a brief physical explanation of the fundamental significance of the EEI related to climate forcing and response, and how global warming and climate change do consequently unfold, see Kirchengast et al. (2021b), Section 2.1 therein; more details are available via von Schuckmann et al. (2020) (both cited below). The SubVariables include the total global EEI (SV3.1) as well as its contributing heat energy increase and energy uptake components from five main subsystems of the Earth system: ocean below uppermost layer (SV3.2), uppermost ocean (SV3.3), land (SV3.4), cryosphere (SV3.5), and atmosphere (SV3.6). All are provided as a decadal increase rate, which for any center year since 1965 (representing 1960-1970) is computed as five-year-smoothed (center year ± 5 years)-linearfit to the respective annual observations of energy uptake or gain since 1960 (provided as the six	

SubVariables of Varia	ble V4 above).
The total EEI increase ZJ/year in the most re- consumption of curre- driven by the ongoing warming starts slowir (see Kirchengast et al and its oceanic and at from El Niño Southerr Ocean Dipole (IOD), a subtracted in a follow anthropogenic climat <i>Related advance info</i> : projections to 2050 or included in follow-on	d from values below 7 ZJ/year before 1990 to values of about 12 to 15 ecent two decades. Comparing this to the world's total annual energy ntly 0.6 ZJ/year, the recent EEI was more than 20 times as large, mainly g global warming and climate change. It will safely shrink again only if global ng down thanks to the success of Paris-compliant global emission reductions ., 2021b; Section 2 therein). Natural inter-annual to decadal variations in EEI emospheric components from atmosphere-ocean variability including effects in Oscillation (ENSO), from the Pacific Decadal Oscillation (PDO), Indian nd the Atlantic Meridional Overturning Circulation (AMOC) may be r-on version, which may further improve the indication of long-term e change. GCClv1 does not yet optionally include change predictions to 2030 and f EEI and its five main components; these are under development and will be versions.
WEGC Kircetal 2021 8	k vSchucketal 2020 & MiscSciSrc
SV5.1	WEGC Kircetal & CWM-DB 2021 & MiscDatSrc
Earth Energy Imbalance (EEI) (total rate of increase)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/cwm (see under "Explanation" above on the variables' computation and see also the further references under SV5.2 to SV5.6 below) Kirchengast et al. (2021c). Section 3 on AHC in von Schuckmann et al. (2020) Heat stored in the Earth system: where does the energy go?. Earth Syst. Sci. Data, 12, 2013-2041 (online at https://essd.copernicus.org/articles/12/2013/2020/#section3) and Kirchengast et al. (2019-2021) Climate trends and variability in Atmospheric Heat Content and atmosphere-ocean heat exchanges etc. IUGG 2019 Conf. Invited Pres. Montreal CA (online https://www.czech- in.org/cmPortalV15/CM W3 Searchable/iugg19/#!sessiondetails/ 0000119801_0), ICGPSRO 2020 Conf. Invited Pres. Hsinchu TW, Manuscript in prep. 2021 (online link added after publication) von Schuckmann et al. (2020). Heat stored in the Earth system: where does the energy go? Earth Syst. Sci. Data, 12, 2013-2041. Online at https://doi.org/10.5194/essd-12-2013-2020
SV5.2	WEGC Kircetal 2021 & vSchucketal 2020 & IAP-ORAS5
Ocean heat content increase rate below UMOHC (depth>300m)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/cwm (see under "Explanation" above on the variables' computation) von Schuckmann et al. (2020). Heat stored in the Earth system: where does the energy go? Earth Syst. Sci. Data, 12, 2013-2041. Online at https://doi.org/10.5194/essd-12-2013-2020 Cheng et al. (2021). Upper ocean temperatures hit record high in 2020. Adv. Atmos. Sci., 38, 523-530. Online at https://doi.org/10.1007/s00376-021-0447-x
	 Zuo et al. (2019). The ECMWF operational ensemble reanalysis-analysis system for ocean and sea ice: a description of the system and assessment. Ocean Sci., 15, 779-808. Online at

		https://doi.org/10.5194/os-15-779-2019
	SV5.3	WEGC Kircetal 2021 & vSchucketal 2020 & IAP-ORAS5
	Uppermost Ocean Heat Content (UMOHC) increase rate (depth 0- 300m)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation)
		 Kirchengast et al. (2021c). Section 3 on AHC in von Schuckmann et al. (2020) Heat stored in the Earth system: where does the energy go?. Earth Syst. Sci. Data, 12, 2013-2041 (online at https://essd.copernicus.org/articles/12/2013/2020/#section3) and Kirchengast et al. (2019-2021) Climate trends and variability in Atmospheric Heat Content and atmosphere-ocean heat exchanges etc. IUGG 2019 Conf. Invited Pres. Montreal CA (online https://www.czech-in.org/cmPortalV15/CM_W3_Searchable/iugg19/#lsessiondetails/0000119801_0), ICGPSRO 2020 Conf. Invited Pres. Hsinchu TW, Manuscript in prep. 2021 (online link added after publication) von Schuckmann et al. (2020). Heat stored in the Earth system: where does the energy go? Earth Syst. Sci. Data, 12, 2013-2041. Online at https://doi.org/10.5194/essd-12-2013-2020 Cheng et al. (2021). Upper ocean temperatures hit record high in 2020. Adv. Atmos. Sci., 38, 523-530. Online at https://doi.org/10.1007/s00376-021-0447-x
		 Zuo et al. (2019). The ECMWF operational ensemble reanalysis-analysis system for ocean and sea ice: a description of the system and assessment. Ocean Sci., 15, 779-808. Online at <u>https://doi.org/10.5194/os-15-779-2019</u>
	SV5.4	vSchucketal 2020 / WEGCupd 2021
	Land heat content increase rate	 von Schuckmann et al. (2020). Heat stored in the Earth system: where does the energy go? Earth Syst. Sci. Data, 12, 2013-2041. Online at <u>https://doi.org/10.5194/essd-12-2013-2020</u>
	SV5.5	vSchucketal 2020 / WEGCupd 2021
	uptake increase rate	 von Schuckmann et al. (2020). Heat stored in the Earth system: where does the energy go? Earth Syst. Sci. Data, 12, 2013-2041. Online at https://doi.org/10.5194/essd-12-2013-2020
	SV5.6 Atmospheric Heat	WEGC Kircetal & CWM-DB 2021 & ERA-JRA-MERRA
	Atmospheric Heat Content (AHC) increase rate	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation)
		 Kirchengast et al. (2021c). Section 3 on AHC in von Schuckmann et al. (2020) Heat stored in the Earth system: where does the energy go?. Earth Syst. Sci. Data, 12, 2013-2041 (online at https://essd.copernicus.org/articles/12/2013/2020/#section3) and Kirchengast et al. (2019-2021) Climate trends and variability in Atmospheric Heat Content and atmosphere-ocean heat exchanges etc. IUGG 2019 Conf. Invited Pres. Montreal CA (online https://www.czechin.org/cmPortalV15/CM_W3_Searchable/iugg19/#!sessiondetails/

		0000119801 0), ICGPSRO 2020 Conf. Invited Pres. Hsinchu TW, Manuscript in prep. 2021 (online link added after publication)
		 Gelaro et al. (2017). The Modern-Era Retrospective Analysis for research and applications, Version 2 (MERRA-2). J. Clim., 30, 5419- 5454. Online at <u>https://doi.org/10.1175/jcli-d-16-0758.1</u>
		 Hersbach et al. (2020). The ERA5 global reanalysis. Q. J. Royal Met. Soc., 146, 1999-2049. Online at <u>https://doi.org/10.1002/qj.3803</u>
		 Japan Meteorological Agency (2013). JRA-55: Japanese 55-year reanalysis, monthly means and variance. Online at <u>https://doi.org/10.5065/D60G3H5B</u>
V6. Earth Energy Imbalance (EEI) per m2 [W/m ²]	Explanation: This is the one that provides conversion from units as the ones of Variable The conversion is imperfulion square meters year (31.558 million s (W/m2)/(ZJ/year). Supower received per so in connection with radius the converted per so in converte	the second of the two Earth Energy Imbalance (EEI) variables of CWM-GLO, is the global EEI over time since the 1960s in units [W/m ²]. Apart from the is [ZJ/year] to units [W/m ²] all SubVariables of this Variable V6 are the same le V5; hence see the Explanation of Variable V5 above for further details. Interest by dividing the (ZJ/year)-values by the Earth surface area (510.06 is for a spherical Earth with radius 6371.0 km) and the number of seconds per econds for 365.25 days per year), yielding a conversion factor of 0.0621 ch expression of energy imbalance or increase rate as the average excess quare meter of the global Earth surface [W/m ²] is widely used in particular diative forcing and response (see Variables V9 and V11).
	WEGC Kircetal 2021 &	& vSchucketal 2020 & MiscSciSrc
	SV6.1	WEGC Kircetal & CWM-DB 2021 & MiscDatSrc
E I I I I	Imbalance (EEI) (total rate of increase)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation and see also the further references under SV6.2 to SV6.6 below)
		 Kirchengast et al. (2021c). Section 3 on AHC in von Schuckmann et al. (2020) Heat stored in the Earth system: where does the energy go?. Earth Syst. Sci. Data, 12, 2013-2041 (online at https://essd.copernicus.org/articles/12/2013/2020/#section3) and Kirchengast et al. (2019-2021) Climate trends and variability in Atmospheric Heat Content and atmosphere-ocean heat exchanges etc. IUGG 2019 Conf. Invited Pres. Montreal CA (online https://www.czech-in.org/cmPortalV15/CM_W3_Searchable/iugg19/#!sessiondetails/0000119801_0), ICGPSRO 2020 Conf. Invited Pres. Hsinchu TW, Manuscript in prep. 2021 (online link added after publication) von Schuckmann et al. (2020). Heat stored in the Earth system: where does the energy go? Earth Syst. Sci. Data, 12, 2013-2041. Online at
		https://doi.org/10.5194/essd-12-2013-2020
	SV6.2 Ocean heat content	WEGC Kircetal 2021 & vSchucketal 2020 & IAP-ORAS5
incr UM (de	increase rate below UMOHC (depth>300m)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation)

		 von Schuckmann et al. (2020). Heat stored in the Earth system: where does the energy go? Earth Syst. Sci. Data, 12, 2013-2041. Online at https://doi.org/10.5194/essd-12-2013-2020
		 Cheng et al. (2021). Upper ocean temperatures hit record high in 2020. Adv. Atmos. Sci., 38, 523-530. Online at <u>https://doi.org/10.1007/s00376-021-0447-x</u>
		 Zuo et al. (2019). The ECMWF operational ensemble reanalysis-analysis system for ocean and sea ice: a description of the system and assessment. Ocean Sci., 15, 779-808. Online at https://doi.org/10.5194/os-15-779-2019
	SV6.3	WEGC Kircetal 2021 & vSchucketal 2020 & IAP-ORAS5
	Uppermost Ocean Heat Content (UMOHC) increase rate (depth 0- 300m)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation)
		 Kirchengast et al. (2021c). Section 3 on AHC in von Schuckmann et al. (2020) Heat stored in the Earth system: where does the energy go?. Earth Syst. Sci. Data, 12, 2013-2041 (online at https://essd.copernicus.org/articles/12/2013/2020/#section3) and Kirchengast et al. (2019-2021) Climate trends and variability in Atmospheric Heat Content and atmosphere-ocean heat exchanges etc. IUGG 2019 Conf. Invited Pres. Montreal CA (online https://www.czech-in.org/cmPortalV15/CM W3 Searchable/iugg19/#lsessiondetails/0000119801_0), ICGPSRO 2020 Conf. Invited Pres. Hsinchu TW, Manuscript in prep. 2021 (online link added after publication) von Schuckmann et al. (2020). Heat stored in the Earth system: where does the energy go? Earth Syst. Sci. Data, 12, 2013-2041. Online at https://doi.org/10.5194/essd-12-2013-2020 Cheng et al. (2021). Upper ocean temperatures hit record high in 2020. Adv. Atmos. Sci., 38, 523-530. Online at https://doi.org/10.1007/s00376-021-0447-x
		 Zuo et al. (2019). The ECMWF operational ensemble reanalysis-analysis system for ocean and sea ice: a description of the system and assessment. Ocean Sci., 15, 779-808. Online at https://doi.org/10.5194/os-15-779-2019
	SV6.4	vSchucketal 2020 / WEGCupd 2021
	increase rate	 von Schuckmann et al. (2020). Heat stored in the Earth system: where does the energy go? Earth Syst. Sci. Data, 12, 2013-2041. Online at https://doi.org/10.5194/essd-12-2013-2020
	SV6.5 Cryospheric energy uptake increase rate	vSchucketal 2020 / WEGCupd 2021
		 von Schuckmann et al. (2020). Heat stored in the Earth system: where does the energy go? Earth Syst. Sci. Data, 12, 2013-2041. Online at <u>https://doi.org/10.5194/essd-12-2013-2020</u>
	SV6.6 Atmospheric Heat Content (AHC) increase rate	WEGC Kircetal & CWM-DB 2021 & ERA-JRA-MERRA
		 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz,

		Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation)
		 Kirchengast et al. (2021c). Section 3 on AHC in von Schuckmann et al. (2020) Heat stored in the Earth system: where does the energy go?. Earth Syst. Sci. Data, 12, 2013-2041 (online at https://essd.copernicus.org/articles/12/2013/2020/#section3) and Kirchengast et al. (2019-2021) Climate trends and variability in Atmospheric Heat Content and atmosphere-ocean heat exchanges etc. IUGG 2019 Conf. Invited Pres. Montreal CA (online https://www.czech-in.org/cmPortalV15/CM W3 Searchable/iugg19/#!sessiondetails/0000119801 0), ICGPSRO 2020 Conf. Invited Pres. Hsinchu TW, Manuscript in prep. 2021 (online link added after publication) Gelaro et al. (2017). The Modern-Era Retrospective Analysis for research and applications, Version 2 (MERRA-2). J. Clim., 30, 5419-5454. Online at https://doi.org/10.1175/jcli-d-16-0758.1 Hersbach et al. (2020). The ERA5 global reanalysis. Q. J. Royal Met. Soc., 146, 1999-2049. Online at https://doi.org/10.1002/gi.3803
		 Japan Meteorological Agency (2013). JRA-55: Japanese 55-year reanalysis, monthly means and variance. Online at <u>https://doi.org/10.5065/D60G3H5B</u>
V7. GHG annual concentrations [ppm]	Explanation: This variations phere since 196 concentration that CC CH ₄ , N ₂ O, etc.) would GHG that has contribuglobal warming (see uradiative forcing). The units of parts per in the air, denote the Earth's atmosphere a (O_2) , termed the main	Table provides annual global greenhouse gas (GHG) concentrations in the 50 in two forms: 1. CO ₂ -equivalent concentration (SV7.1), which is the D ₂ would have in the air if the total radiative forcing of all GHGs (incl. also come from CO ₂ only, and 2. the concentration of just CO ₂ , which is the main uted about 80% of the radiative forcing increase since 1990 that drives under CWM-GLO for a range of global warming-related variables, including million [ppm], used for expressing concentrations of trace gases such as CO ₂ number of molecules of a trace gas per million of total air molecules. In bout 99% of this total are made up by molecular nitrogen (N ₂) and oxygen in constituents of the air.
	NOAA 2021& Meineta	al 2017/2020& WEGC 2021
	SV7.1	NOAA 2021 & Meinsh-etal 2017 & Etmin-etal 2016 / WEGCupd 2021
	CO2-equivalent concentration (all GHGs)	 Meinshausen et al. (2017). <i>Historical greenhouse gas concentrations for climate modelling (CMIP6)</i>. Geosci. Model Dev., 10, 2057-2116. Online at https://doi.org/10.5194/gmd-10-2057-2017
		 Butler and Montzka-NOAA (2021). The NOAA Annual Greenhouse Gas Index (AGGI). Online at https://gml.noaa.gov/aggi/aggi.html
		 Meinshausen et al. (2020). The shared socio-economic pathway (SSP) greenhouse gas concentrations and their extensions to 2500. Geosci. Model Dev., 13, 8, 3571-3605. Online at https://doi.org/10.5194/gmd-13-3571-2020
	SV7.2	NOAA 2021 & Meinsh-etal 2017 / WEGCupd 2021
	(no other GHGs)	 Meinshausen et al. (2017). <i>Historical greenhouse gas concentrations for climate modelling (CMIP6)</i>. Geosci. Model Dev., 10, 2057-2116. Online at https://doi.org/10.5194/gmd-10-2057-2017
		 Butler and Montzka-NOAA (2021). The NOAA Annual Greenhouse Gas

		Index (AGGI). Online at <u>https://gml.noaa.gov/aggi/aggi.html</u>
V8. Effective radiative forcing [ZJ/year]	Explanation: This is of one that annually pro- $((1 ZJ = 10^{21} J = 1 trillicconsumption is currentthe Explanations underemission of CO2 and contre-missions and countre-part of the ERF see Bu-The SubVariables incl-into five main compo-(SV8.2), other small aand CO2 forcing (SV8.forcing up to the yearThe total ERF increase45 ZJ/year in the mos-greenhouse gas emissionglobal emission reduct$	ne of the two Effective Radiative Forcing (ERF) variables of CWM-GLO, the vides the global ERF since 1960 as accumulated from 1750 in units [ZJ/year] on gigajoules of energy; for comparison, the world's total annual energy ntly about 0.6 ZJ). The ERF and its increase, driving the climate response (see er Variables V3 and V11), occur mainly due to continued anthropogenic other greenhouse gases (GHGs) as shown in GEM-GLO for the global ies worldwide. For a closer explanation of the main forcing components as utler and Montzka-NOAA (2021) and Smith et al. (2020) (both cited below). ude the total global ERF (SV8.1) as well as its contributing forcings divided nent forcings (with the most prominent listed last): natural volcanic+solar nthropogenic (SV8.3), anthropogenic aerosol (SV8.4), other GHGs (SV8.5), 6), respectively. All are provided as annual values expressing the respective accrued since 1750 (i.e., since preindustrial). ed from values near 10ZJ/year in 1960 (since 1750) to values of about 35 to it recent decade as of 2010. This forcing will gradually begin to stop only if sions are significantly reduced thanks to the success of Paris-compliant ctions (see Kirchengast et al., 2021b; Section 2 therein) (cited below).
	SV8.1	WEGC Kircetal&CWM-DB 2021 & NOAA & Smithetal & MiscSciSrc
	Effective radiative forcing (total) (from 1750)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation)
		 Kirchengast et al. (2021b). Carbon Management: A new approach to achieve Paris-compliant climate goals. WEGC Research Briefs 1-2021, Wegener Center Verlag, Univ. of Graz, Austria. Online at <u>https://doi.org/10.25364/23.2021.1</u> (Section 2 at <u>https://unipub.uni- graz.at/obvugrveroeff/content/pageview/6047842</u>)
		 Butler and Montzka-NOAA (2021). The NOAA Annual Greenhouse Gas Index (AGGI). Online at https://gml.noaa.gov/aggi/aggi.html
		 Smith et al. (2021). Energy budget constraints on the time history of aerosol forcing and climate sensitivity. J. Geophys. Res. Atmos., 126, e2020JD033622. Online at <u>https://doi.org/10.1029/2020JD033622</u>
		 Hoesly, R. M. et al. (2018). <i>Historical (1750–2014) anthropogenic emissions of reactive gases and aerosols from the Community Emissions Data System (CEDS)</i>. Geoscientific Model Development, 11, 1, 369–408. <u>https://doi.org/10.5194/gmd-11-369-2018</u>
		 Skeie, R. B. et al. (2020). <i>Historical total ozone radiative forcing derived from CMIP6 simulations</i>. Npj Climate and Atmospheric Science, 3, 1, 1–10. <u>https://doi.org/10.1038/s41612-020-00131-0</u>
		 Coddington et al. (2015). NOAA Climate Data Record (CDR) of Total Solar Irradiance (TSI), NRLTSI Version 2. Online at <u>https://doi.org/10.7289/V55B00C1</u>
		 Ghimire et al. (2014). Global albedo change and radiative cooling from anthropogenic land cover change, 1700 to 2005 based on MODIS, land use harmonization, radiative kernels, and reanalysis. Geophys. Res. Lett., 41, 9087-9096. Online at <u>https://doi.org/10.1002/2014gl061671</u>

		 Kovilakam et al. (2020). The Global Space-based Stratospheric Aerosol Climatology (version 2.0): 1979-2018. Earth Syst. Sci. Data, 12, 2607- 2634. Online at <u>https://doi.org/10.5194/essd-12-2607-2020</u>
		 Lee et al. (2021). The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. Atmos. Environ., 244, 117834. Online at <u>https://doi.org/10.1016/j.atmosenv.2020.117834</u>
		 Luo (2018). Release Notes Stratospheric Aerosol Radiative Forcing and SAD version v4.0.0 1850-2016. Online at <u>ftp://iacftp.ethz.ch/pub</u> <u>read/luo/CMIP6 SAD radForcing v4.0.0/Release note v4.0.0.pdf</u> (last access: 1 April 2021)
		 Meinshausen et al. (2017). <i>Historical greenhouse gas concentrations for climate modelling (CMIP6)</i>. Geosci. Model Dev., 10, 2057-2116. Online at https://doi.org/10.5194/gmd-10-2057-2017
		 Myhre et al. (2013). Anthropogenic and Natural Radiative Forcing. pp. 659-740. Cambridge Univ. Press, Cambridge, UK. Online at <u>https://doi.org/10.1017/cbo9781107415324.018</u>
		 Yeo et al. (2017). EMPIRE: A robust empirical reconstruction of solar irradiance variability. J. Geophys. Res. Space Phys., 122, 3888-3914. Online at <u>https://doi.org/10.1002/2016ja023733</u>
	SV8.2	WEGC Kircetal 2021 & NOAA 2020 & Luo 2018 & Yeoetal 2017
	Natural volcanic+solar radiative forcing (from 1750)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/cwm (see under "Explanation" above on the variables' computation)
		 Coddington et al. (2015). NOAA Climate Data Record (CDR) of Total Solar Irradiance (TSI), NRLTSI Version 2. Online at <u>https://doi.org/10.7289/V55B00C1</u>
		 Kovilakam et al. (2020). The Global Space-based Stratospheric Aerosol Climatology (version 2.0): 1979-2018. Earth Syst. Sci. Data, 12, 2607- 2634. Online at <u>https://doi.org/10.5194/essd-12-2607-2020</u>
		 Luo (2018). Release Notes Stratospheric Aerosol Radiative Forcing and SAD version v4.0.0 1850-2016. Online at <u>ftp://iacftp.ethz.ch/pub</u> <u>read/luo/CMIP6 SAD radForcing v4.0.0/Release note v4.0.0.pdf</u> (last access: 1 April 2021)
		 Yeo et al. (2017). EMPIRE: A robust empirical reconstruction of solar irradiance variability. J. Geophys. Res. Space Phys., 122, 3888-3914. Online at <u>https://doi.org/10.1002/2016ja023733</u>
	SV8.3 Other (small)	WEGC Kircetal 2021 & Checa-Garcia-etal 2018 & MiscSciSrc
	anthropogenic – radiative forcings (from 1750)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation)
		 Hoesly, R. M. et al. (2018). <i>Historical (1750–2014) anthropogenic emissions of reactive gases and aerosols from the Community Emissions Data System (CEDS)</i>. Geoscientific Model Development, 11, 1, 369–408. <u>https://doi.org/10.5194/gmd-11-369-2018</u>
		 Skeie, R. B. et al. (2020). <i>Historical total ozone radiative forcing derived</i> from CMIP6 simulations. Npj Climate and Atmospheric Science, 3, 1, 1–

		10 https://doi.org/10.1038/s41612-020-00131-0
		 Ghimire et al. (2014). Global albedo change and radiative cooling from anthropogenic land cover change, 1700 to 2005 based on MODIS, land use harmonization, radiative kernels, and reanalysis. Geophys. Res. Lett., 41, 9087-9096. Online at https://doi.org/10.1002/2014gl061671
		 Lee et al. (2021). The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. Atmos. Environ., 244, 117834. Online at https://doi.org/10.1016/j.atmosenv.2020.117834
		 Myhre et al. (2013). Anthropogenic and Natural Radiative Forcing. pp. 659-740. Cambridge Univ. Press, Cambridge, UK. Online at <u>https://doi.org/10.1017/cbo9781107415324.018</u>
	SV8.4	WEGC Kircetal 2021 & Smithetal2021
	Anthropogenic aerosol radiative forcing (from 1750)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation)
		 Smith et al. (2021). Energy budget constraints on the time history of aerosol forcing and climate sensitivity. J. Geophys. Res. Atmos., 126, e2020JD033622. Online at <u>https://doi.org/10.1029/2020JD033622</u>
	SV8.5	WEGC Kircetal 2021 & NOAA 2021 & Meinsetal 2017
	anthropogenic GHGs radiative forcing (from 1750)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation)
		 Butler and Montzka-NOAA (2021). The NOAA Annual Greenhouse Gas Index (AGGI). Online at <u>https://gml.noaa.gov/aggi/aggi.html</u>
		 Meinshausen, M. et al. (2020). The shared socio-economic pathway (SSP) greenhouse gas concentrations and their extensions to 2500. Geoscientific Model Development, 13, 8, 3571–3605. Online at https://doi.org/10.5194/gmd-13-3571-2020
		 Meinshausen et al. (2017). <i>Historical greenhouse gas concentrations for climate modelling (CMIP6)</i>. Geosci. Model Dev., 10, 2057-2116. Online at https://doi.org/10.5194/gmd-10-2057-2017
	SV8.6	WEGC Kircetal 2021 & NOAA 2021 & Meinsetal 2017
	radiative forcing (from 1750)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation)
		 Butler and Montzka-NOAA (2021). The NOAA Annual Greenhouse Gas Index (AGGI). Online at <u>https://gml.noaa.gov/aggi/aggi.html</u>
		 Meinshausen et al. (2017). <i>Historical greenhouse gas concentrations for climate modelling (CMIP6).</i> Geosci. Model Dev., 10, 2057-2116. Online at <u>https://doi.org/10.5194/gmd-10-2057-2017</u>
		 International et al. (2017). Historical greenhouse gas concentrations for climate modelling (CMIP6). Geosci. Model Dev., 10, 2057-2116. Online at https://doi.org/10.5194/gmd-10-2057-2017

V9. Effective radiative forcing per m2 [W/m ²]	Explanation: This is the second of the two Effective Radiative Forcing (ERF) variables of CWM- GLO, the one that provides the global ERF since 1960 as accumulated from 1750 in units [W/m ²]. Apart from the conversion from units [ZJ/year] to units [W/m ²] all SubVariables of this Variable V9 are the same as the ones of Variable V8; hence see the Explanation of Variable V8 above for further details. The conversion is implemented by dividing the (ZJ/year)-values by the Earth surface area (510.06 trillion square meters for a spherical Earth with radius 6371.0 km) and the number of seconds per year (31.558 million seconds for 365.25 days per year), yielding a conversion factor of 0.0621 (W/m2)/(ZJ/year). Such expression of the ERF as an average power per square meter of the global Earth surface [W/m ²] is widely used, in fact quite more commonly than the units [ZJ/year], in particular in connection with joint radiative forcing and response estimates (see Variable V11).		
	SV9 1	WEGC Kircetal&CWM-DB 2021 & NOAA & Smithetal & MiscSciSrc	
	Effective radiative forcing (total) (from 1750)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation) 	
		 Kirchengast et al. (2021b). Carbon Management: A new approach to achieve Paris-compliant climate goals. WEGC Research Briefs 1-2021, Wegener Center Verlag, Univ. of Graz, Austria. Online at <u>https://doi.org/10.25364/23.2021.1</u> (Section 2 at <u>https://unipub.uni- graz.at/obvugrveroeff/content/pageview/6047842</u>) 	
		 Butler and Montzka-NOAA (2021). The NOAA Annual Greenhouse Gas Index (AGGI). Online at <u>https://gml.noaa.gov/aggi/aggi.html</u> 	
		 Smith et al. (2021). Energy budget constraints on the time history of aerosol forcing and climate sensitivity. J. Geophys. Res. Atmos., 126, e2020JD033622. Online at <u>https://doi.org/10.1029/2020JD033622</u> 	
		 Hoesly, R. M. et al. (2018). <i>Historical (1750–2014) anthropogenic emissions of reactive gases and aerosols from the Community Emissions Data System (CEDS)</i>. Geoscientific Model Development, 11, 1, 369–408. <u>https://doi.org/10.5194/gmd-11-369-2018</u> 	
		 Skeie, R. B. et al. (2020). <i>Historical total ozone radiative forcing derived from CMIP6 simulations</i>. Npj Climate and Atmospheric Science, 3, 1, 1–10. <u>https://doi.org/10.1038/s41612-020-00131-0</u> 	
		 Coddington et al. (2015). NOAA Climate Data Record (CDR) of Total Solar Irradiance (TSI), NRLTSI Version 2. Online at <u>https://doi.org/10.7289/V55B00C1</u> 	
		 Ghimire et al. (2014). Global albedo change and radiative cooling from anthropogenic land cover change, 1700 to 2005 based on MODIS, land use harmonization, radiative kernels, and reanalysis. Geophys. Res. Lett., 41, 9087-9096. Online at <u>https://doi.org/10.1002/2014gl061671</u> 	
		 Kovilakam et al. (2020). The Global Space-based Stratospheric Aerosol Climatology (version 2.0): 1979-2018. Earth Syst. Sci. Data, 12, 2607- 2634. Online at <u>https://doi.org/10.5194/essd-12-2607-2020</u> 	
		 Lee et al. (2021). The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. Atmos. Environ., 244, 117834. Online at <u>https://doi.org/10.1016/j.atmosenv.2020.117834</u> 	
		 Luo (2018). Release Notes Stratospheric Aerosol Radiative Forcing and SAD version v4.0.0 1850-2016. Online at <u>ftp://iacftp.ethz.ch/pub</u> read/luo/CMIP6 SAD radForcing v4.0.0/Release note v4.0.0.pdf (last 	

		access: 1 April 2021)
		 Meinshausen et al. (2017). <i>Historical greenhouse gas concentrations for climate modelling (CMIP6).</i> Geosci. Model Dev., 10, 2057-2116. Online at https://doi.org/10.5194/gmd-10-2057-2017
		 Myhre et al. (2013). Anthropogenic and Natural Radiative Forcing. pp. 659-740. Cambridge Univ. Press, Cambridge, UK. Online at <u>https://doi.org/10.1017/cbo9781107415324.018</u>
		 Yeo et al. (2017). EMPIRE: A robust empirical reconstruction of solar irradiance variability. J. Geophys. Res. Space Phys., 122, 3888-3914. Online at <u>https://doi.org/10.1002/2016ja023733</u>
	SV9.2	WEGC Kircetal 2021 & NOAA 2020 & Luo 2018 & Yeoetal 2017
	Natural volcanic+solar radiative forcing (from 1750)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation) Coddington et al. (2015). NOAA Climate Data Record (CDR) of Total
		Solar Irradiance (TSI), NRLTSI Version 2. Online at https://doi.org/10.7289/V55B00C1
		 Kovilakam et al. (2020). The Global Space-based Stratospheric Aerosol Climatology (version 2.0): 1979-2018. Earth Syst. Sci. Data, 12, 2607- 2634. Online at <u>https://doi.org/10.5194/essd-12-2607-2020</u>
		 Luo (2018). Release Notes Stratospheric Aerosol Radiative Forcing and SAD version v4.0.0 1850-2016. Online at <u>ftp://iacftp.ethz.ch/pub</u> <u>read/luo/CMIP6 SAD radForcing v4.0.0/Release note v4.0.0.pdf</u> (last access: 1 April 2021)
		 Yeo et al. (2017). EMPIRE: A robust empirical reconstruction of solar irradiance variability. J. Geophys. Res. Space Phys., 122, 3888-3914. Online at <u>https://doi.org/10.1002/2016ja023733</u>
	SV9.3	WEGC Kircetal 2021 & Checa-Garcia-etal 2018 & MiscSciSrc
Other (sma anthropog radiative fo (from 1750	anthropogenic radiative forcings (from 1750)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation)
		 Hoesly, R. M. et al. (2018). <i>Historical (1750–2014) anthropogenic emissions of reactive gases and aerosols from the Community Emissions Data System (CEDS)</i>. Geoscientific Model Development, 11, 1, 369–408. <u>https://doi.org/10.5194/gmd-11-369-2018</u>
		 Skeie, R. B. et al. (2020). <i>Historical total ozone radiative forcing derived from CMIP6 simulations</i>. Npj Climate and Atmospheric Science, 3, 1, 1–10. <u>https://doi.org/10.1038/s41612-020-00131-0</u>
		 Ghimire et al. (2014). Global albedo change and radiative cooling from anthropogenic land cover change, 1700 to 2005 based on MODIS, land use harmonization, radiative kernels, and reanalysis. Geophys. Res. Lett., 41, 9087-9096. Online at <u>https://doi.org/10.1002/2014gl061671</u>
		 Lee et al. (2021). The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. Atmos. Environ., 244, 117834. Online at <u>https://doi.org/10.1016/j.atmosenv.2020.117834</u>

		 Myhre et al. (2013). Anthropogenic and Natural Radiative Forcing. pp. 659-740. Cambridge Univ. Press, Cambridge, UK. Online at <u>https://doi.org/10.1017/cbo9781107415324.018</u>
	SV9.4	WEGC Kircetal 2021 & Smithetal2021
	Anthropogenic aerosol radiative forcing (from 1750)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at www.gcci.earth/global/cwm (see under "Explanation" above on the variables' computation) Smith et al. (2021). Energy budget constraints on the time history of aerosol forcing and climate sensitivity. J. Geophys. Res. Atmos., 126, e2020JD033622. Online at <u>https://doi.org/10.1029/2020JD033622</u>
	SV9.5	WEGC Kircetal 2021 & NOAA 2021 & Meinsetal 2017
	anthropogenic GHGs radiative forcing (from 1750)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation)
		 Butler and Montzka-NOAA (2021). The NOAA Annual Greenhouse Gas Index (AGGI). Online at <u>https://gml.noaa.gov/aggi/aggi.html</u>
		 Meinshausen, M. et al. (2020). The shared socio-economic pathway (SSP) greenhouse gas concentrations and their extensions to 2500. Geoscientific Model Development, 13, 8, 3571–3605. Online at https://doi.org/10.5194/gmd-13-3571-2020
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	SV9.6 Anthropogenic CO2 radiative forcing (from 1750)	WEGC Kircetal 2021 & NOAA 2021 & Meinsetal 2017
		 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation)
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		 Meinshausen et al. (2017). <i>Historical greenhouse gas concentrations for climate modelling (CMIP6)</i>. Geosci. Model Dev., 10, 2057-2116. Online at https://doi.org/10.5194/gmd-10-2057-2017
V10. Global surface air temperature [°C]	Explanation: This is the included in form of an SV10.1 as temperature GSAT datasets, with m Following the latter state a close proxy to the time a close proxy to the time diative forcing (ERF The GSAT data are uss 1.4 Wm ⁻² /K) in order to state a close V11.2 and SVM	The global surface air temperature (GSAT) variable of CWM-GLO that is sinual-mean GSAT data since 1960. These are contained in its SubVariable re change data relative to preindustrial, constructed from state-of-the-art most weight given to the recent HadCRUT5 data of Morice et al. (2021). tudy, "preindustrial" is taken to be the 1850-1900 average which was found ime period around 1750 as is used as preindustrial reference in the effective) data (see Variables V8 and V9). ed as a product with a best estimate climate feedback parameter (α_{FP} ; set to to obtain a radiative response estimate (RRE) as included in Variable 11 as well as the related index Variable V3 (SubVariable V3.3). For a brief

	physical explanation on how the climate forcing (ERF) and climate response (RRE) act together, and are related in their difference to the EEI, see Kirchengast et al. (2021b), Section 2.1 therein.		
	WEGC Kircetal 2021 8	& HadCRUT5-NASAGIST4-ERA5T	
	SV10.1 Global surface air temperature change (vs Preindustrial)	WEGC Kircetal 2021 & HadCRUT5-NASAGIST4-ERA5T	
Global s temper change Preindu		 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation) 	
		 Kirchengast et al. (2021b). Carbon Management: A new approach to achieve Paris-compliant climate goals. WEGC Research Briefs 1-2021, Wegener Center Verlag, Univ. of Graz, Austria. Online at <u>https://doi.org/10.25364/23.2021.1</u> (Section 2.1 at <u>https://unipub.uni- graz.at/obvugrveroeff/content/pageview/6047842</u>) 	
		 Morice et al. (2021). An updated assessment of near-surface temperature change from 1850: The HadCRUT5 data set. J. Geophys. Res. Atmos., 126, e2019JD032361. Online at <u>https://doi.org/10.1029/2019jd032361</u> 	
		 GISTEMP Team (2021). GISS Surface Temperature Analysis (GISTEMP), version 4. NASA Goddard Institute for Space Studies. Online at <u>https://data.giss.nasa.gov/gistemp/</u> 	
		 Lenssen et al. (2019). Improvements in the GISTEMP uncertainty model. J. Geophys. Res. Atmos., 124, 6307-6326. Online at https://doi.org/10.1029/2018jd029522 	
		 Hersbach et al. (2020). <i>The ERA5 global reanalysis</i>. Q. J. Royal Met. Soc., 146, 1999-2049. Online at <u>https://doi.org/10.1002/qj.3803</u> 	
V11. Forcing- Response- Imbalance estimates [W/m ²]	Explanation: This is the Energy Imbalance (EE Response Estimate (R widening gap betweet anthropogenic climate gases (GHGs) as show physical explanation of and climate response see Kirchengast et al. et al. (2020) (both cite The SubVariables incl RRE (SV11.3) estimate the difference betweet which roughly corresp estimation from Earth constructed for the p small solar forcing ter mean construction the The EEI expresses the year shown. It is com observations of total Variable V4). Similarly moving-averages; the the latter as the prod	the variable of CWM-GLO that collects the estimates of the global Earth increase and the related Effective Radiative Forcing (ERF) and Radiative IRE) increases since the 1960s. The EEI and its increase, linked to a still in the ERF and (lagging) RRE increases, occur mainly due to the ongoing e change caused by the continued emission of CO_2 and other greenhouse or in GEM-GLO for the global emissions and countries worldwide. For a brief of the fundamental significance of the EEI related to climate forcing (ERF) (RRE), and how global warming and climate change do consequently unfold, (2021b), Section 2.1 therein; more details are available via von Schuckmann ed below). ude the global EEI (SV11.1) as well as the related global ERF (SV11.2) and es, respectively. The fourth SubVariable (SV11.4) shows for completeness en the forcing and response estimates (i.e., between SV11.2 an SV11.3), ponds to the EEI (up to some natural variability in the EEI due to its n system-internal heat gain and energy uptake data). The ERF estimates are urpose here without the intermittent and episodic natural volcanic and the rms, in order to focus on the anthropogenic forcing (due to the decadal- is makes a small difference only, however). e decadal increase rate of energy uptake in the Earth system in any center puted as five-year-smoothed (center year ± 5 years)-linearfit to the annual Earth energy uptake since 1960 (i.e., it is equal to SubVariable SV4.1 of γ , the ERF and RRE estimates are computed as (center year ± 5 years)- e former based on the annual total anthropogenic ERF data of Variable V9, uct of a best-estimate total climate feedback parameter (α_{FP} ; 1.4 Wm ⁻² /K)	

	Response estimate (S the best-estimate val	Response estimate (SV11.4) confirms, from its overall consistency with the EEI estimate (SV11.1), the best-estimate value of the feedback parameter.		
	WEGC Kircetal 2021 & ERF-RRESAT-EEI MiscSciSrc			
	SV11.1 Earth Energy Imbalance (EEI) observation (decadal)	WEGC Kircetal 2021 & vSchucketal 2020 & MiscSciSrc		
		 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation) 		
		 Kirchengast et al. (2021b). Carbon Management: A new approach to achieve Paris-compliant climate goals. WEGC Research Briefs 1-2021, Wegener Center Verlag, Univ. of Graz, Austria. Online at <u>https://doi.org/10.25364/23.2021.1</u> (Section 2.1 at <u>https://unipub.uni- graz.at/obvugrveroeff/content/pageview/6047842</u>) 		
		 Kirchengast et al. (2021c). Section 3 on AHC in von Schuckmann et al. (2020) Heat stored in the Earth system: where does the energy go?. Earth Syst. Sci. Data, 12, 2013-2041 (online at https://essd.copernicus.org/articles/12/2013/2020/#section3) and Kirchengast et al. (2019-2021) Climate trends and variability in Atmospheric Heat Content and atmosphere-ocean heat exchanges etc. IUGG 2019 Conf. Invited Pres. Montreal CA (online https://www.czech-in.org/cmPortalV15/CM_W3_Searchable/iugg19/#lsessiondetails/0000119801_0), ICGPSRO 2020 Conf. Invited Pres. Hsinchu TW, Manuscript in prep. 2021 (online link added after publication) 		
		 von Schuckmann et al. (2020). Heat stored in the Earth system: where does the energy go? Earth Syst. Sci. Data, 12, 2013-2041. Online at https://doi.org/10.5194/essd-12-2013-2020 		
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	SV11.2 Effective radiative forcing (decadal) (from 1750)	WEGC Kircetal 2021 & NOAA 2021 & Smithetal & MiscSciSrc		
		 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation) 		

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		 Meinshausen et al. (2017). <i>Historical greenhouse gas concentrations for climate modelling (CMIP6)</i>. Geosci. Model Dev., 10, 2057-2116. Online at https://doi.org/10.5194/gmd-10-2057-2017
		 Myhre et al. (2013). Anthropogenic and Natural Radiative Forcing. pp. 659-740. Cambridge Univ. Press, Cambridge, UK. Online at <u>https://doi.org/10.1017/cbo9781107415324.018</u>
	SV11.3	WEGC Kircetal 2021 & HadCRUT5-NASAGIST4-ERA5T
	Radiative response estimate (decadal) (from 1750)	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO. DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u> (see under "Explanation" above on the variables' computation)
		 Morice et al. (2021). An updated assessment of near-surface temperature change from 1850: The HadCRUT5 data set. J. Geophys. Res. Atmos., 126, e2019JD032361. Online at <u>https://doi.org/10.1029/2019jd032361</u>
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	SV11.4	WEGC Kircetal 2021 & CWM-DB & MiscDatSrc
	Response	 Kirchengast et al. (2021). Graz Climate Change Indicators (GCCI) Content and References Information Sheets—InfoSheet CWM-GLO.
	(decadal)	DocID GCCIv1.2-CWM-GLO-Apr2022, Wegener Center, Univ. of Graz, Austria. Online at <u>www.gcci.earth/global/cwm</u>

	see the SV11.2 and SV11.3 references above on the forcing and response estimates themselves)