Supplementary Materials

The Effect of Climate Change-Induced Temperature Increase on Animal Performance and Environmental Impact of Intensive Pig Production Systems

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Table S1: Sources, model assumptions and parameters of functions for important production traits of confined pigs in temperate Western European agriculture

	(Sow plus) Suckling Piglets	**Weaned Piglets**	**Growing and Finishing Pigs**
Literature sources	GfE (2006) [1], Dyck and Swierstra (1987) [2], LfL (2014) [3]	GfE (2006) [1], LfL (2014) [3]	GfE (2006) [1], LfL (2014) [3]
Body mass gain			
Model assumption and parameters	Gompertz function C = 1.693 L = 0.558 K = 0.195	Gompertz function C = 1.466 L = 0.540 K = 0.130	Gompertz function C = 21.534 L = 0.186 K = 0.082
Cumulative feed intake			
Model assumption and parameters	Gompertz function[a] C = 0.325 L = 1.263 K = 0.105	Gompertz function C = 0.279 L = 0.860 K = 0.118	Gompertz function C = 12.500 L = 0.353 K = 0.091
Feed conversion			
Model assumption and parameters		Polynomial function a = 0.046 b = −0.241 c = 1.770	Gompertz function C = 2.549 L = 0.001 K = −0.235
Mortality			
Model assumption and parameters	Gompertz function C = 4.73×10^{-5} L = 30.395 K = 3.776	Gompertz function C = 7.64×10^{-7} L = 6.149 K = 0.602	Linear funtion a = 9.20×10^{-4} b = 0.0001

[a] Including the sow's feed for the lactating phase only.

Table S1: List of literature sources defining temperature requirements, thermo-neutral zones, heat stress-temperatures and effects of increasing temperature on production traits

Temperature Requirements, Thermo-Neutral Zones and Heat Stress	**Temperature Effects on Production Traits**
	Kyriazakis and Whittemore, 2006 [7]
	Hyun et al., 1998 [8]
	Kouba et al., 2001 [9]
	Becker et al., 1992 [10]
	Song, et al., 2011 [11]
	Lefaucheur et al., 1991 [12]
	Le Dividich et al., 1980 [13]
Troxler and Menke (2006) [4]	Weller et al., 2013 [14]
Bracke (2011) [5]	Collin et al., 2002 [15]
Pig Site (2018) [6]	Lopez et al., 1991 [16]
Kyriazakis and Whittemore (2006) [7]	White et al., 2008 [17]
	Dividich, 1981 [18]
	Rinaldo and Le Dividich, 1991 [19]
	Rinaldo et al., 2000 [20]
	Collin et al., 2001a [21]
	Collin et al., 2001b [22]
	Ferguson and Gous, 1997 [23]
	Oliveira and Donzele, 1999 [24]

Table S2: Composition of the sow diet (average over the whole production cycle) plus piglet feed and the average growing-finishing pig diet in percent (on 88 % dry matter basis)

Ingredient	**Proportions in Average Sow Diet (%)**	**Proportions in Average Growing - Finishing Pig Diet (%)**
Maize	35 %	57 %
Soybean meal, extracted	15 %	16 %
Barley	17 %	15 %
Wheat (Wheat bran)	15 % (5 %)	6 % (1 %)
Rapeseed meal, extracted	4 %	-
Sunflower seed meal, extracted	4 %	-
Soybean oil	-	1 %
Calcium carbonate and sodium chloride	3 %	2 %
Calcium phosphate, other minerals, synthetic amino acids, lignocellulose	2 %	2 %

Table S3: Inputs other than feed and sources given as specific energy demand related to animal places or body mass

Inputs (Unit of Measurement)	Average Values	Data Source, Comment
Electricity demand of livestock building including energy for the ventilation system (MJ per kg body mass gain piglet & growing-fattening pig), for low temperature (year 1984)/high temperature (year 2003)/worst case temperature	0.3/0.4/0.5	Calculated based on unpublished primary data from farm surveys and Mikovits *et al.* (2019) [25]
Electricity for heating, infrared lamp (MJ per kg body mass gain piglet)	9.6[a]	Calculated based on Büscher (2006) [26]
Electricity demand feed mill (MJ per kg body mass gain piglet & growing-fattening pig)	0.3	Energy demand from GEMIS (v 4.7; Fritsche and Schmidt, 2007) [27] multiplied by feed intake
Transports by tractor (transport of manure, etc.; ton-km per kg body mass gain piglet & growing-fattening pig)	0.05	Calculated for manure application with 5 km distance (including the return path)
Drinking and cleaning water (m^3 per kg body mass gain piglet & growing-fattening pig)	0.01	Calculated based on DLG (2008) [28]

[a] 0.6 MJ per kg body mass gain finished pig

Table S4: Biogenic emissions (kg/kg body mass) as annual mean for the low temperature scenario for reared piglet and for growing-finishing pig (at farm-gate before slaughtering)

Emissions Per kg Body Mass Gain	Annual Mean Emission for Piglets: kg/kg Reared Piglet	Annual Mean Emission for Growing-Finishing Pigs: kg/kg Finished Pig
kg NH_3	0.0269	0.0625
kg NO_X	0.00001	0.00002
kg N_2O	0.00031	0.00072
kg CH_4	0.0094	0.0145
kg NO_3	0.0306	0.0710

Table S6: Elements related to climate change impacts in the feed production system

System Elements	The Systems Elements Describe…
Active elements (showing impacts on other system elements)	
Climate change impacts (abiotic CCI)	… driving forces behind abiotic CCIs (increase in air temperature, etc.) and thus a significant factor influencing crop production
Genetic potential of crops (concerning CCI)	... the use of crops that are tolerant or resistant due to their genetic predisposition to diseases or abiotic CCIs
Irrigation	... the use or / and installation of irrigation systems
Passive elements (receiving impacts from other system elements)	
Crop yields	... high yields as an optimisation goal in the system analysis
Dependence on technology and energy	... as an undesirable situation
Ambivalent elements (having impacts on other system elements, but at the same time receive strong effects from other elements)	
Biotic CCIs	... pathogen-related (harvest-) losses in crop production
Measures to increase the socio-economic resilience of production systems (PS) in general	… measures for socio-economic resilient PS; e.g., diversification of sources of income, the use of insurance options or investments into CCI-relevant infrastructure
Biogenic structures to increase agro-ecological resilience in crop production	... measures to protect biodiversity or soils, e.g. hedges or permanent greening
(Change of) Factor costs for agricultural land	... the impact of changing factor costs for land due to soil depletion or climate-induced yield changes
Positive farm's financial situation	... the socio-economic well-being of farmers; an optimization goal in the analysis
Buffering elements (showing a buffering effect on a system)	
Site-specific adjustment of inputs (intensity) and outputs	... a specific site adaptation measure and the PS that significantly contributes to maintaining or enhancing resilience
Cooperation with other companies	... a specific and important measure to maintain or promote socio-economic resilience in the PS
Insurances – crops and infra-structure	... a specific and significant measure to maintain or promote socio-economic resilience in the PS

The attributions ("active", "passive", "ambivalent" and "buffering") are automatically derived results of the system analysis (software Systaim SystemQ). Especially categorizations for ambivalent and buffering factors are sometimes difficult, as there may be transitions between these groups.

Table S7: Elements related to climate change impacts and livestock

System Elements	The Systems Elements Describe…
Active elements (showing impacts on other system elements)	
Measures against direct CCI in housing systems	... the effects of, for example, fans, shading, showers, air conditioning, etc. on animal welfare, health and productivity
Health plans and activities against diseases related to CCI	... measures that proactively tackle CCI-related animal health problems
Solutions to maintain farm power supply	... to be prepared against power (electricity) failure, i.a. for ventilation, air conditioning systems and water supply
Water supply	... the situation regarding the availability of sufficient drinking water
Passive elements (receiving impacts from other system elements)	
Farm's financial situation	... the economic performance of the farm, including results of long-term profitability
Livestock yields	... the level of animal productivity
Animal welfare / health	... the realized degree of animal welfare / health
Ambivalent elements (having impacts on other system elements, but at the same time receive strong effects from other elements)	
Diseases and losses related to CCI	... the incidence of illnesses and losses related to CCI
Buffering elements (showing a buffering effect on a system)	
Genetic potential of livestock	... the use of pig genotypes that are tolerant or resistant against abiotic CCI-impacts and CCI-related diseases
Feed supply	... the availability of feed of appropriate quality
Insurances	... which are more or less important to maintain or promote socio-economic resilience (for buildings, crops and/or livestock)
Changing requirements for animal products due to society / politics / NGOs	... a situation in which the demand for animal products changes, because, for instance, political measures have a positive or inhibiting effect

The attributions ("active", "passive", "ambivalent" and "buffering") are automatically derived results of the system analysis (software Systaim SystemQ). Especially categorizations for ambivalent and buffering factors are sometimes difficult, as there may be transitions between these groups. .

Table S8: Thermoneutral zones (TNZ) of domesticated pigs (°C)

Animal Category	Average of Literature	Minimum	Maximum
Suckling piglets (<7 kg)	26–32	22	33
Weaned piglets (8-30 kg)	23–29	20	30
Growing pigs (30-60 kg)	19-22	18	25
Finishing pigs (>60 kg)	17–21	15	24
Sows, after weaning	16–20	15	20
Sows, lactating	18–22	16	22
Boars	18	16	19

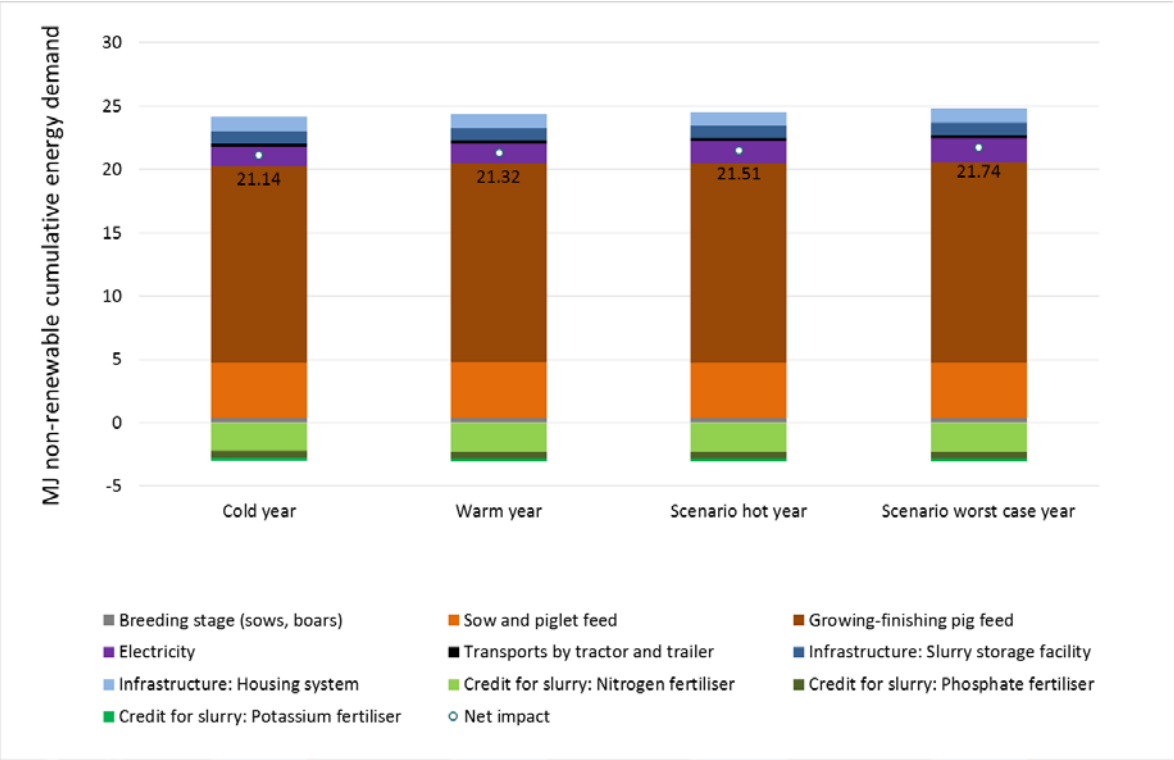

Figure S1. Use of fossil energy (CED non-renewable) in MJ per kg body mass at farm-gate.

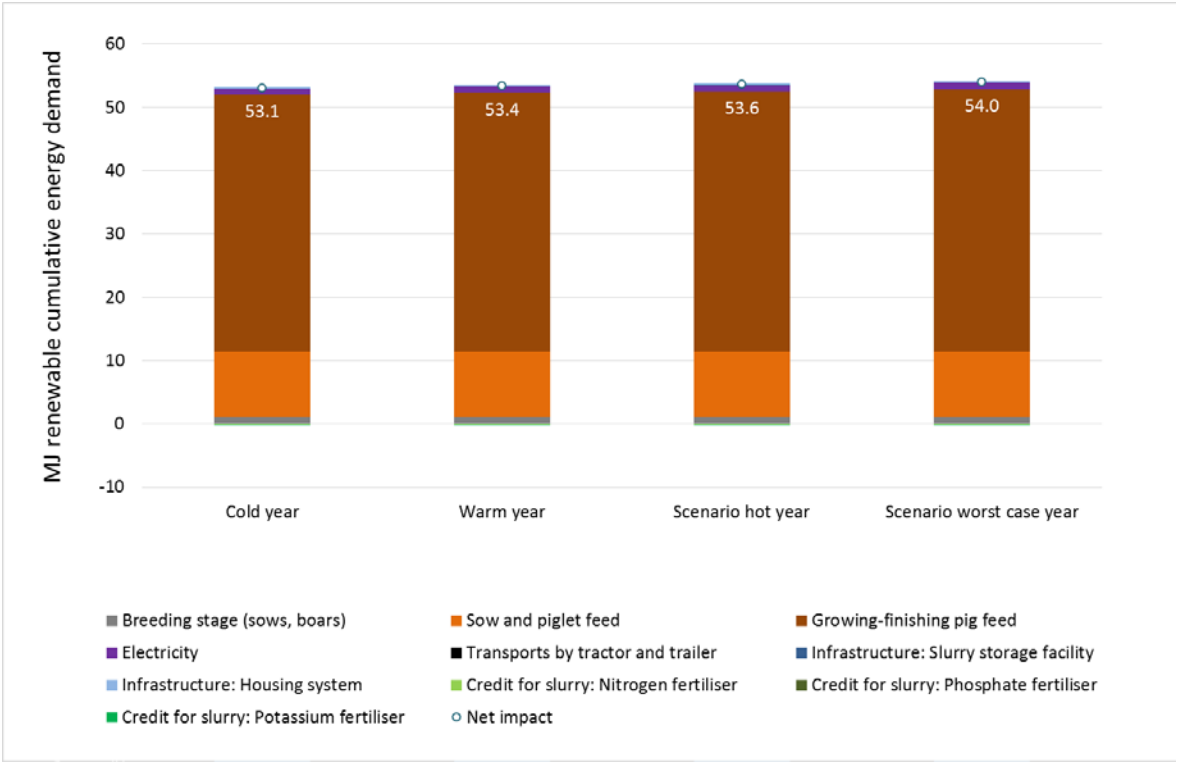

Figure S2: Use of renewable energy (CED renewable) in MJ per kg body mass at farm-gate

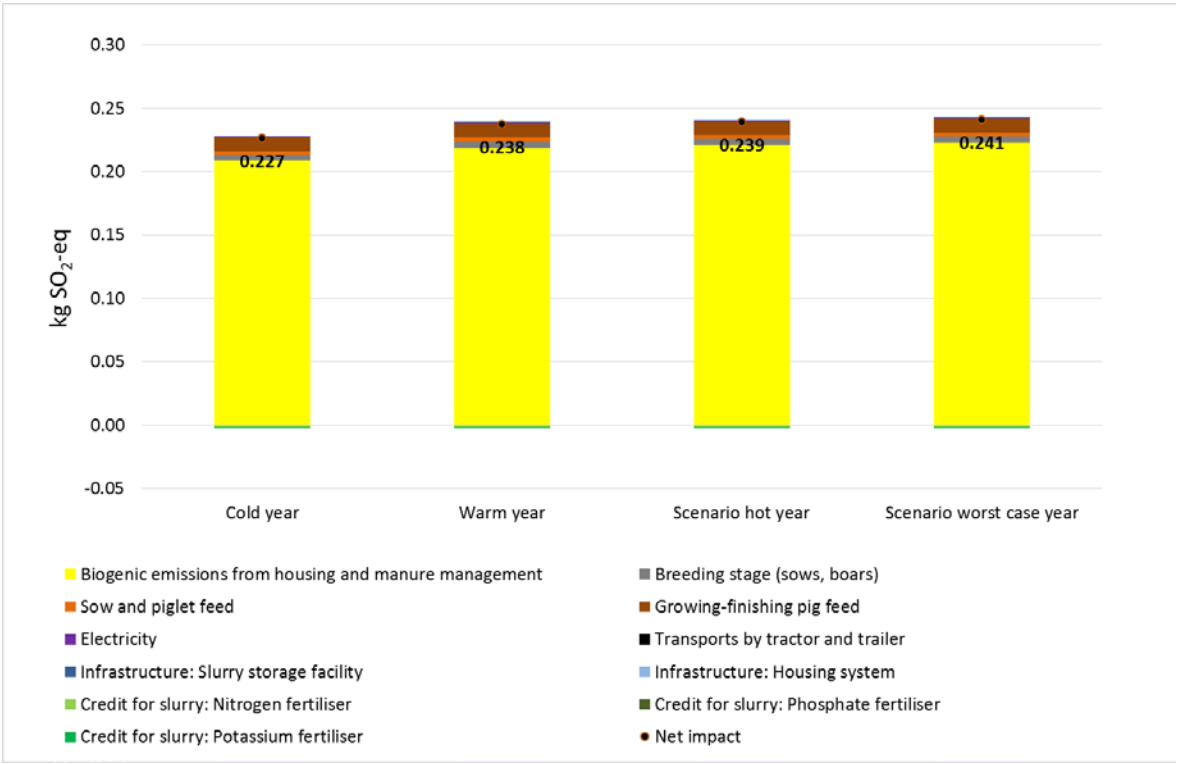

Figure S1: Acidification potential (AP) in kg SO_2-eq per kg body mass at farm-gate

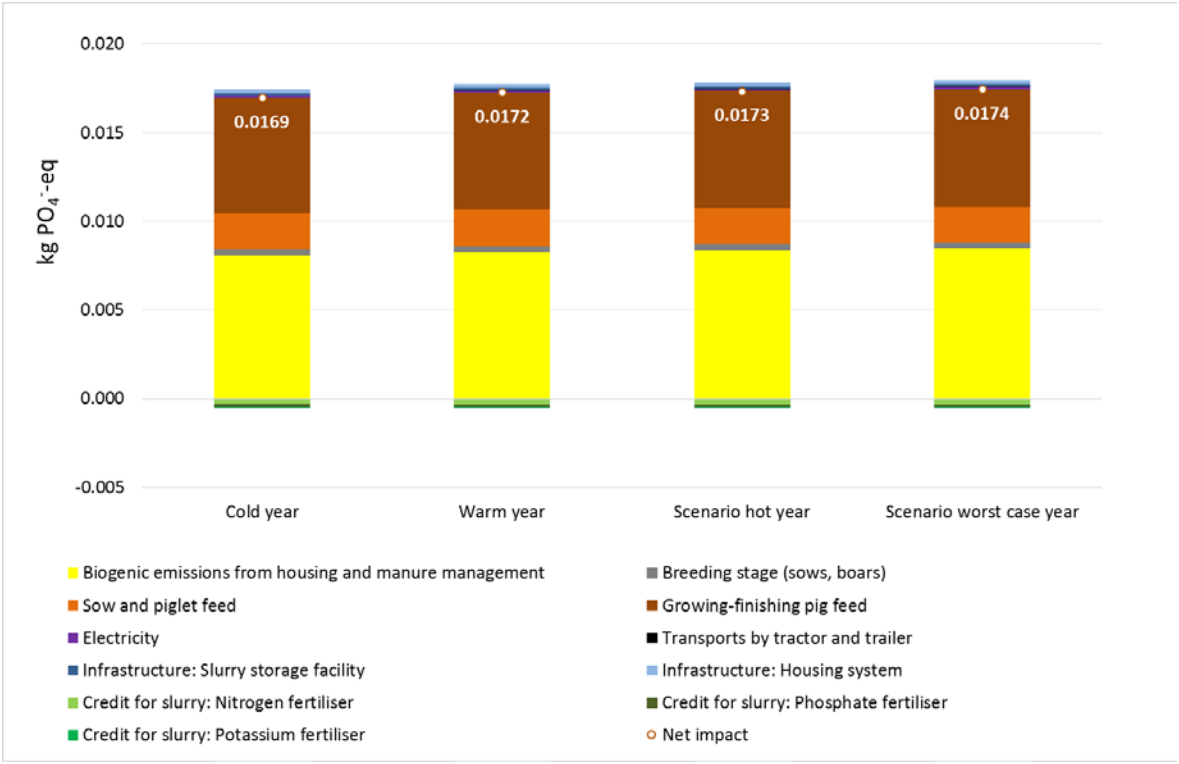

Figure S4: Eutrophication potential (EP) in kg PO_4^--eq per kg body mass at farm-gate

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