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Expert opinion related to case number 24-036810ASD-BORG/02

Brussels, 23/06/2024

In case number 24-036810ASD-BORG/02, I have been asked by 'Föreningen Greenpeace Norden' and 'Natur og Ungdom' to address the following questions:

1. How many children born in 2010-2020 worldwide are expected to face one extra heatwave due to the emissions of Tyrving, Breidablikk, and Yggdrasil, in isolation and all combined?
2. How many children born in 2010-2020 worldwide are expected to face one extra other climate extreme due to the emissions of Tyrving, Breidablikk, and Yggdrasil, in isolation and all combined?
3. How many heat-related deaths are expected worldwide until 2100 due to the emissions of Tyrving, Breidablikk, and Yggdrasil, in isolation and all combined?
4. What are the answers to questions 1 to 3 if one considers the annual emissions of Tyrving and Breidablikk in 2024 and 2025, as well as the annual emissions of Yggdrasil in 2027 and 2028, instead of their total emissions?

The following emission values were provided to me by 'Föreningen Greenpeace Norden':

	Emissions ($MtCO_2eq$) used as input in the calculations			
Time period	**Tyrving**	**Breidablikk**	**Yggdrasil**	**Combined**
Total	12	87	365	464
2024	0.435	10.143	-	-
2025	3.170	10.143	-	-
2026	-	-	-	-
2027	-	-	28.8	-
2028	-	-	42.4	-

I use this information as input data for the calculations and assume that these values are accurate.

Here below I provide my answers to these four questions.

Regarding question 1; The following table provides the number of children born in a particular calendar year worldwide expected to face one additional heatwave due to the total emissions of Tyrving, Breidablikk, Yggdrasil, and all three combined. A heatwave is defined here following Thiery et al. (2021 *Science*[1]) as a multi-day extreme heat event that is expected to occur only once per century in absence of climate change.

[1] Thiery, W., Lange, S., Rogelj, J., Schleussner, C.-F., Gudmundsson, L., Seneviratne, S.I., Frieler, K., Emanuel, K., Geiger, T., Bresch, D.N., Zhao, F., Willner, S.N., Büchner, M., Volkholz, J., Andrijevic, M., Bauer, N., Chang, J., Ciais, P., Dury, M., François, L., Grillakis, M., Gosling, S.N., Hanasaki, N., Hickler, T., Huber, V., Ito, A., Jägermeyr, J., Khabarov, N., Koutroulis, A., Liu, W., Lutz, W., Mengel, M., Müller, C., Ostberg, S., Reyer, C.P.O., Stacke,

	Number of children facing an additional **heatwave** due to the **total** emissions of			
Birth year	**Tyrving**	**Breidablikk**	**Yggdrasil**	**Combined**
2020	7380	53512	224504	285397
2019	7173	52006	218188	277368
2018	6968	50524	211972	269466
2017	6773	49104	206014	261892
2016	6577	47689	200076	254343
2015	6384	46290	194207	246882
2014	6187	44859	188201	239248
2013	5990	43432	182217	231640
2012	5760	41760	175201	222721
2011	5531	40103	168250	213885
2010	5312	38518	161598	205429
2010-2020	**70035**	**507797**	**2130428**	**2708271**

The results[2] imply, for example, that

- 53 512 children born in the year 2020 are expected to face one additional heatwave in their lifetime due to the total emissions of Breidablikk.
- 269 466 children born in the year 2018 are expected to face one additional heatwave in their lifetime due to the total emissions of Tyrving, Breidablikk, and Yggdrasil combined.
- 2 708 271 children born in the years 2010 to 2020 are expected to face one additional heatwave in their lifetime due to the total emissions of Tyrving, Breidablikk, and Yggdrasil combined.

Regarding question 2; The following tables provide the number of children born in a particular calendar year worldwide expected to face one additional drought, crop failure, wildfire, tropical cyclone, or river flood due to the total emissions of Tyrving, Breidablikk, Yggdrasil, and all three combined. The definitions of all climate extremes and means of calculating their annual occurrence are provides in Thiery et al. (2021 *Science*).

	Number of children facing an additional **drought** due to the **total** emissions of			
Birth year	**Tyrving**	**Breidablikk**	**Yggdrasil**	**Combined**
2020	238	1728	7249	9216
2019	228	1659	6960	8848
2018	219	1588	6664	8472
2017	210	1527	6407	8144
2016	203	1475	6191	7871
2015	196	1424	5975	7595
2014	188	1369	5744	7302
2013	183	1329	5579	7092
2012	173	1257	5276	6707
2011	163	1188	4986	6339
2010	155	1125	4721	6002
2010-2020	**2156**	**15669**	**65752**	**83588**

	Number of children facing an additional **crop failure** due to the **total** emissions of			
Birth year	**Tyrving**	**Breidablikk**	**Yggdrasil**	**Combined**
2020	199	1447	6072	7719
2019	195	1416	5942	7553
2018	190	1384	5808	7383
2017	186	1353	5678	7218
2016	182	1322	5549	7054
2015	179	1298	5449	6927

T., Wada, Y., Intergenerational inequities in exposure to climate extremes, ***Science***, 374(6564), 158-160. [pdf, Research highlight in Nature, Nature Climate Change, and The Lancet Planetary Health].

[2] Note that these numbers slightly differ from the numbers communicated during my intervention as expert witness in first instance, because (i) the emission estimates I received as input were updated following new information about production, and (ii) I now use a more accurate number for the Transient Climate Response to Cumulative Emissions (TCRE): 0.45°C per 1000 Gt CO_2eq instead of 0.5°C per 1000 Gt CO_2eq (the latter number was used in first instance and is a rounding of the former).

2014	174	1263	5302	6740
2013	170	1234	5180	6585
2012	165	1197	5023	6385
2011	160	1165	4889	6215
2010	156	1133	4753	6043
2010-2020	**1956**	**14212**	**59645**	**75822**

Number of children facing an additional **wildfire** due to the **total** emissions of

Birth year	**Tyrving**	**Breidablikk**	**Yggdrasil**	**Combined**
2020	76	554	2328	2959
2019	75	545	2287	2907
2018	73	534	2240	2848
2017	71	521	2187	2781
2016	70	508	2134	2712
2015	68	499	2097	2665
2014	67	488	2048	2603
2013	65	475	1995	2536
2012	63	458	1923	2445
2011	61	445	1868	2374
2010	59	429	1803	2292
2010-2020	**748**	**5456**	**22910**	**29122**

Number of children facing an additional **tropical cyclone** due to the **total** emissions of

Birth year	**Tyrving**	**Breidablikk**	**Yggdrasil**	**Combined**
2020	72	527	2212	2812
2019	71	515	2163	2749
2018	69	504	2116	2690
2017	67	492	2067	2628
2016	66	482	2025	2575
2015	65	473	1987	2526
2014	64	464	1946	2474
2013	62	451	1894	2408
2012	59	431	1809	2300
2011	56	413	1733	2203
2010	54	396	1662	2113
2010-2020	**705**	**5148**	**21614**	**27478**

Number of children facing an additional **river flood** due to the **total** emissions of

Birth year	**Tyrving**	**Breidablikk**	**Yggdrasil**	**Combined**
2020	53	389	1633	2077
2019	51	376	1581	2010
2018	49	362	1519	1931
2017	47	347	1458	1854
2016	46	335	1406	1788
2015	44	322	1354	1722
2014	43	312	1310	1665
2013	41	301	1266	1610
2012	39	288	1209	1537
2011	37	275	1154	1467
2010	36	262	1101	1400
2010-2020	**486**	**3569**	**14991**	**19061**

The results imply, for example, that

- 83 588 children born in the years 2010 to 2020 are expected to face one additional drought in their lifetime due to the total emissions of Tyrving, Breidablikk, and Yggdrasil combined.
- 75 822 children born in the years 2010 to 2020 are expected to face one additional crop failure in their lifetime due to the total emissions of Tyrving, Breidablikk, and Yggdrasil combined.

- 29 122 children born in the years 2010 to 2020 are expected to face one additional wildfire in their lifetime due to the total emissions of Tyrving, Breidablikk, and Yggdrasil combined.
- 27 478 children born in the years 2010 to 2020 are expected to face one additional tropical cyclone in their lifetime due to the total emissions of Tyrving, Breidablikk, and Yggdrasil combined.
- 19 061 children born in the years 2010 to 2020 are expected to face one additional river flood in their lifetime due to the total emissions of Tyrving, Breidablikk, and Yggdrasil combined.

Regarding question 3; The following table provides the number of heat-related deaths expected worldwide until 2100 due to the total emissions of Tyrving, Breidablikk, Yggdrasil, and all three combined.

	Number of **heat-related deaths until 2100** due to the **total** emissions of			
	Tyrving	**Breidablikk**	**Yggdrasil**	**Combined**
Additional heat-related deaths until 2100	2706	19621	82318	104645

The results[3] imply that
- 2 706 heat-related deaths are expected worldwide until 2100 due to the total emissions of Tyrving.
- 19 621 heat-related deaths are expected worldwide until 2100 due to the total emissions of Breidablikk.
- 82 318 heat-related deaths are expected worldwide until 2100 due to the total emissions of Yggdrasil.
- 104 645 heat-related deaths are expected worldwide until 2100 due to the total emissions of Tyrving, Breidablikk, and Yggdrasil combined.

Regarding question 4; The following table provides the number of children born in a particular birth year worldwide expected to face one additional heatwave, drought, wildfire, tropical cyclone, crop failure, or river flood due to the emissions of Tyrving and Breidablikk in the calendar years 2024, 2025, and Yggdrasil in the calendar years 2027 and 2028.

	Number of children facing an additional **heatwave** due to the **annual** emissions of					
	Tyrving 2024	**Tyrving 2025**	**Breidablikk 2024**	**Breidablikk 2025**	**Yggdrasil 2027**	**Yggdrasil 2028**
Birth year						
2020	267	1949	6238	6238	17714	26079
2019	260	1894	6063	6063	17215	25345
2018	252	1840	5890	5890	16725	24623
2017	245	1789	5724	5724	16255	23931
2016	238	1737	5559	5559	15786	23241
2015	231	1686	5396	5396	15323	22559
2014	224	1634	5229	5229	14849	21862
2013	217	1582	5063	5063	14377	21167
2012	208	1521	4868	4868	13824	20352
2011	200	1461	4675	4675	13275	19544
2010	192	1403	4490	4490	12750	18771
2010-2020	**2534**	**18496**	**59195**	**59195**	**168093**	**247474**

	Number of children facing an additional **drought** due to the **annual** emissions of					
	Tyrving 2024	**Tyrving 2025**	**Breidablikk 2024**	**Breidablikk 2025**	**Yggdrasil 2027**	**Yggdrasil 2028**
Birth year						
2020	8	62	201	201	572	842
2019	8	60	193	193	549	808
2018	7	57	185	185	525	774
2017	7	55	178	178	505	744
2016	7	53	172	172	488	719
2015	7	51	166	166	471	694
2014	6	49	159	159	453	667

[3] Note that these numbers slightly differ from the numbers communicated during my intervention as expert witness in first instance, because the emission estimates I received as input were slightly different.

2013	6	48	155	155	440	648
2012	6	45	146	146	416	612
2011	5	43	138	138	393	579
2010	5	41	131	131	372	548
2010-2020	**72**	**564**	**1824**	**1824**	**5184**	**7635**

Number of children facing an additional **crop failure** due to the **annual** emissions of

Birth year	**Tyrving 2024**	**Tyrving 2025**	**Breidablikk 2024**	**Breidablikk 2025**	**Yggdrasil 2027**	**Yggdrasil 2028**
2020	7	52	168	168	479	705
2019	7	51	165	165	468	690
2018	6	50	161	161	458	674
2017	6	49	157	157	448	659
2016	6	48	154	154	437	644
2015	6	47	151	151	429	633
2014	6	46	147	147	418	615
2013	6	44	143	143	408	601
2012	5	43	139	139	396	583
2011	5	42	135	135	385	568
2010	5	41	132	132	375	552
2010-2020	**65**	**513**	**1652**	**1652**	**4701**	**6924**

Number of children facing an additional **wildfire** due to the **annual** emissions of

Birth year	**Tyrving 2024**	**Tyrving 2025**	**Breidablikk 2024**	**Breidablikk 2025**	**Yggdrasil 2027**	**Yggdrasil 2028**
2020	2	20	64	64	183	270
2019	2	19	63	63	180	265
2018	2	19	62	62	176	260
2017	2	19	60	60	172	254
2016	2	18	59	59	168	247
2015	2	18	58	58	165	243
2014	2	17	56	56	161	237
2013	2	17	55	55	157	231
2012	2	16	53	53	151	223
2011	2	16	51	51	147	217
2010	2	15	50	50	142	209
2010-2020	**22**	**194**	**631**	**631**	**1802**	**2656**

Number of children facing an additional **tropical cyclone** due to the **annual** emissions of

Birth year	**Tyrving 2024**	**Tyrving 2025**	**Breidablikk 2024**	**Breidablikk 2025**	**Yggdrasil 2027**	**Yggdrasil 2028**
2020	2	19	61	61	174	256
2019	2	18	60	60	170	251
2018	2	18	58	58	167	245
2017	2	17	57	57	163	240
2016	2	17	56	56	159	235
2015	2	17	55	55	156	230
2014	2	16	54	54	153	226
2013	2	16	52	52	149	220
2012	2	15	50	50	142	210
2011	2	15	48	48	136	201
2010	1	14	46	46	131	193
2010-2020	**21**	**182**	**597**	**597**	**1700**	**2507**

Number of children facing an additional **river flood** due to the **annual** emissions of

Birth year	**Tyrving**	**Tyrving**	**Breidablikk**	**Breidablikk**	**Yggdrasil**	**Yggdrasil**

	2024	2025	2024	2025	2027	2028
2020	1	14	45	45	128	189
2019	1	13	43	43	124	183
2018	1	13	42	42	119	176
2017	1	12	40	40	115	169
2016	1	12	39	39	111	163
2015	1	11	37	37	106	157
2014	1	11	36	36	103	152
2013	1	11	35	35	99	147
2012	1	10	33	33	95	140
2011	1	10	32	32	91	134
2010	1	9	30	30	86	127
2010-2020	**11**	**126**	**412**	**412**	**1177**	**1737**

The results imply, for example, that

- 6 238 children born in the year 2020 are expected to face one additional heatwave in their lifetime due to the emissions of Breidablikk in the year 2024.
- 5 184 children born in the years 2010 to 2020 are expected to face one additional drought in their lifetime due to the emissions of Yggdrasil in the year 2027.
- 6 924 children born in the years 2010 to 2020 are expected to face one additional crop failure in their lifetime due to the emissions of Yggdrasil in the year 2028.

	Number of **heat-related deaths until 2100** due to the **annual** emissions of					
	Tyrving 2024	**Tyrving 2025**	**Breidablikk 2024**	**Breidablikk 2025**	**Yggdrasil 2027**	**Yggdrasil 2028**
Additional heat-related mortality until 2100	98	714	2287	2287	6495	9562

The results imply that

- 98 heat-related deaths are expected worldwide until 2100 due to the emissions of Tyrving in 2024.
- 714 heat-related deaths are expected worldwide until 2100 due to the emissions of Tyrving in 2025.
- 2 287 heat-related deaths are expected worldwide until 2100 due to the emissions of Breidablikk in 2024.
- 2 287 heat-related deaths are expected worldwide until 2100 due to the emissions of Breidablikk in 2025.
- 6 495 heat-related deaths are expected worldwide until 2100 due to the emissions of Yggdrasil in 2027.
- 9 562 heat-related deaths are expected worldwide until 2100 due to the emissions of Yggdrasil in 2028.

As also mentioned during my testimony of 30 November 2023, the numbers shown here represent the *best estimate*, that is, the central number expected given the employed scientific information. The actual number could be lower, but could equally well be higher, depending on the imprecision of the numbers that were used as input in the calculations. These input values include, for question 1 and 2: the total greenhouse gas emission estimates for Tyrving, Breidablikk and Yggdrasil (see first table), the transient climate response to cumulative emissions (TCRE; 0,45°C per 1000 Gt CO_2eq), the birth cohort size for 2010-2020 birth cohorts (obtained from the Wittgenstein Center), the sensitivity of lifetime heatwave, drought, crop failure, wildfire, tropical cyclone, and river flood exposure to global mean temperature rise (derived from Thiery et al., 2021 *Science*[4]). The results were obtained by first multiplying the respective emission values with the TCRE to obtain the global warming linked to the emissions. This value was then multiplied with the change in lifetime extreme event exposure per degree of warming for the respective climate extremes, to obtain the number of climate extremes additionally experienced by the average birth cohort member. Finally, this value was multiplied with the cohort size for the respective birth years to obtain the number of members from a birth cohort experiencing one additional climate extreme. For question 3, the input values include: the total greenhouse gas emission estimates for Tyrving, Breidablikk and Yggdrasil (see first table) and the mortality cost of carbon (1 extra heat-related death until 2100 per 4434 t CO_2eq; Bressler, 2021 *Nature Communications*[5]). The results were obtained by multiplying the emission values with the mortality cost of

[4] Thiery, W., et al., op. cit.

[5] Bressler, R. D. (2021). The mortality cost of carbon. **Nature communications**, 12(1), 4467. [pdf]

carbon. For question 4, the input values include the same inputs as in the previous questions, except for the greenhouse gas emission estimates for Tyrving, Breidablikk and Yggdrasil, where we use annual instead of total values (see first table). The calculation were performed analogous to the ones of questions 1-3.

I hereby confirm that I have made these calculations in full scientific independence, and that I have not received any remuneration for this work, nor for any previous work related to this case.

Sincerely yours,

Prof. Wim Thiery
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