SUPPORTING INFORMATION FOR:

Dolan, S. and G.A. Heath. 2012. Life Cycle Greenhouse Gas Emissions of Utility-Scale Wind Power: Systematic Review and Harmonization. *Journal of Industrial Ecology.*

Summary

This supporting information provides further detail on the screening process, GHG emissions by life cycle and harmonization stage, and rationale for the system boundary harmonization approach.

Selection of Harmonization Level

To decide which level of harmonization was appropriate for a given electricity generation technology, a two-stage quantitative test was developed. These tests were meant to inform decisions on how to allocate scarce resources to the development of more robust estimates of central tendency and variability that could inform decision-makers in the near term, not as the ideal statistical approach. First, the standard deviation (SD) and interquartile range (IQR), which equals 75th minus 25th percentile value, of published estimates of life cycle greenhouse gas (GHG) emissions, in grams of carbon dioxide-equivalents per kilowatt hour (CO_2eq/kWh), were compared to the arithmetic mean of the pool of estimates from literature passing the quality and relevance screens. Variability in published estimates was deemed high if the SD and IQR were greater than or equal to 50% of the mean and low if less than 50%. Second, the range of published estimates (maximum - minimum value) was compared to the mean value for estimates for pulverized coal from literature collected in the Life Cycle Assessment (LCA) Harmonization Project that passed the screens for quality and relevance, which was 1,100 g CO_2eq/kWh (Whitaker et al., 2011). If the range was greater than or equal to 10% of the mean value for pulverized coal, i.e., 110 g

CO_2eq/kWh, published variability was considered significant. When, according to these tests, variability in a given electricity generation technology's published estimates are deemed low and not significant relative to coal, the less resource-intensive level of harmonization appeared sufficient to achieve the project goals. For the case of wind power technologies, both the SD and IQR were greater than 50% of the mean value so the first criterion for light harmonization was not met. However, the range of estimates for wind power is less than 10% the mean value for coal, meeting the second criterion for light harmonization. Further, since the median value for wind power is nearly two orders of magnitude less than that of coal, the light level of harmonization was deemed appropriate in this situation.

Effects of Harmonizing to Higher Capacity Factors

The harmonization step that had the greatest effect on reducing variability in the pool of life cycle GHG emission estimates was harmonization of capacity factor. For comparison, table S1 presents side-by-side summary statistics for harmonizing onshore estimates to capacity factors of 30% and 35%, and offshore estimates to 40% and 45%. The mean estimate for all values decreases an additional 11 percentage points from the published values upon increasing the assumed capacity factor by 5%. Further, the standard deviation also decreases by an additional 10 percentage points upon increasing the assumed capacity factor by 5%. This is a result of the estimates getting smaller, on average, in proportion to the increase in assumed capacity factor, which means that the estimates are getting closer together in absolute terms.

Table S1. Harmonization of capacity factors to more optimistic benchmark values.

		Published	Harmonized to 30% CF for onshore, 40% CF for offshore	% change from published	Harmonized to 35% CF for onshore, 45% CF for offshore	% change from published
All Values	Mean (g CO_2eq/kWh)	16	14	-11%	12	-23%
	Std Dev (g CO_2eq/kWh)	14	11	-26%	9.0	-37%
	Minimum (g CO_2eq/kWh)	1.7	2.1	20%	1.8	2.9%
	25th percentile (g CO_2eq/kWh)	7.9	7.2	-9.4%	6.2	-22%
	Median (g CO_2eq/kWh)	12	10	-16%	8.9	-26%
	75th percentile (g CO_2eq/kWh)	20	18	-12%	15	-23%
	Maximum (g CO_2eq/kWh)	81	48	-41%	41	-49%
	IQR (g CO_2eq/kWh)	12	10	-14%	9.3	-23%
	Range (max-min) (g CO_2eq/kWh)	79	46	-42%	39	-50%
	Estimates	125	119		118	
	References	49	46		45	
Onshore	Mean (g CO_2eq/kWh)	16	14	-12%	12	-24%
	Std Dev (g CO_2eq/kWh)	15	11	-26%	9.6	-37%
	Minimum (g CO_2eq/kWh)	1.7	2.1	20%	1.8	2.9%
	25th percentile (g CO_2eq/kWh)	7.4	6.9	-6.3%	5.9	-20%
	Median (g CO_2eq/kWh)	12	9.6	-20%	8.2	-32%
	75th percentile (g CO_2eq/kWh)	20	18	-10%	16	-22%
	Maximum (g CO_2eq/kWh)	81	48	-41%	41	-49%
	IQR (g CO_2eq/kWh)	13	11	-12%	10	-24%
	Range (max-min) (g CO_2eq/kWh)	79	46	-42%	39	-50%
	Estimates	107	105		105	
	References	44	42		42	
Offshore	Mean (g CO_2eq/kWh)	13	12	-7.1%	11	-16%
	Std Dev (g CO_2eq/kWh)	5.2	3.9	-25%	3.8	-27%
	Minimum (g CO_2eq/kWh)	5.3	7.2	35%	6.4	20%
	25th percentile (g CO_2eq/kWh)	9.4	9.6	2.3%	8.9	-5.8%
	Median (g CO_2eq/kWh)	12	11	-13%	9.5	-23%
	75th percentile (g CO_2eq/kWh)	14	15	7.3%	14	-4.6%
	Maximum (g CO_2eq/kWh)	24	22	-8.3%	22	-8%
	IQR (g CO_2eq/kWh)	5.0	5.8	17%	4.9	-2.3%
	Range (max-min) (g CO_2eq/kWh)	19	15	-21%	16	-16%
	Estimates	16	14		14	
	References	12	10		10	

Disaggregated GHG Emissions by Life Cycle Stage

Life cycle GHG emissions disaggregated by life cycle stage are presented on the basis of g CO_2eq/kWh in the manuscript in order to determine add-on values for the harmonization process. Table S2 provides the same information but on a capacity basis for the upstream and downstream life cycle stages (g CO_2eq/MW). The reasoning for this is that upstream and downstream emissions correlate better to the size of the power system rather than to the amount of electricity generated over the life cycle. The GHG emissions for the ongoing life cycle stage remain in the g CO_2eq/kWh units since these emissions do correlate to the lifetime power generation.

For the system boundary harmonization step, two sets of add-on values were generated. The first set is based on published disaggregated estimates and used for the independent system boundary harmonization step. It was also necessary to calculate a second set of add-on values based on disaggregated estimates that are first harmonized by their respective GWPs, lifetimes, and capacity factors. These add-on values were used in the cumulative harmonization step to avoid adding non-harmonized data onto harmonized data. The published median add-on values were 1.4 and 0.41 g CO_2eq/kWh for onshore turbines and 0.44 and 0.50 g CO_2eq/kWh for offshore turbines for ongoing and downstream stages, respectively. The harmonized median add-on values were 1.3 and 0.44 g CO_2eq/kWh for onshore turbines and 0.50 and 0.56 g CO_2eq/kWh for offshore turbines for ongoing and downstream stages, respectively (table S3).

Table S2. GHG emission estimates disaggregated by life cycle stage (on a capacity basis for the upstream and downstream life cycle stages, and generation basis for the ongoing stage)

		Upstream	Ongoing	Downstream
All Values	Mean	860	1.5	31
	Std Dev	620	1.6	18
	Minimum	194	0.10	3.1
	25% percentile	370	0.35	18
	Median	620	0.66	27
	75th percentile	1100	2.3	39
	Max	2300	6.7	95
	Percent of Total	86%	8.7%	5.2%
	Estimates	65	33	29
	References	22	15	13
Onshore	Mean	880	1.9	27
	Std Dev	660	1.7	15
	Minimum	190	0.12	3.1
	25% percentile	360	0.48	18
	Median	620	1.3	22
	75th percentile	1100	3.1	38
	Max	2300	6.7	64
	Percent of Total	86%	10%	4.3%
	Estimates	57	24	21
	References	20	12	11
Offshore	Mean	710	0.37	41
	Std Dev	210	0.17	22
	Minimum	530	0.10	16
	25% percentile	610	0.25	27
	Median	660	0.50	39
	75th percentile	690	0.50	40
	Max	1200	0.50	95
	Percent of Total	87%	5.5%	7.4%
	Estimates	8	7	8
	References	5	6	4

Table S3. Results of the disaggregation of GHG emissions by life cycle stage for both published data and data previously harmonized by GWPs, system lifetime, and capacity factor.

		Published Upstream	Harmonized Upstream	Published Ongoing	Harmonized Ongoing	Published Downstream	Harmonized Downstream
All Values	Mean (g CO_2eq/kWh)	16	16	1.9	1.5	0.52	0.52
	Median (g CO_2eq/kWh)	10	10	0.77	0.66	0.47	0.50
	Std Dev (g CO_2eq/kWh)	16	12	2.4	1.6	0.31	0.31
	Contribution to Total	88%	86%	6%	8.7%	4%	5.2%
	Estimates	68	68	33	33	30	30
	References	25	25	15	15	14	14
Onshore	Mean (g CO_2eq/kWh)	16	17	2.4	1.9	0.51	0.50
	Median (g CO_2eq/kWh)	10	11	1.4	1.3	0.41	0.44
	Std Dev (g CO_2eq/kWh)	17	12	2.6	1.7	0.33	0.30
	Contribution to Total	88%	86%	7.3%	10%	3.2%	4.3%
	Estimates	59	59	24	24	22	22
	References	22	22	12	12	12	12
Offshore	Mean (g CO_2eq/kWh)	12	11	0.34	0.37	0.57	0.58
	Median (g CO_2eq/kWh)	8.9	9.5	0.44	0.50	0.50	0.56
	Std Dev (g CO_2eq/kWh)	5.8	4.4	0.13	0.17	0.24	0.32
	Contribution to Total	90%	87%	4.6%	5.5%	5.3%	7.4%
	Estimates	9	9	7	7	8	8
	References	6	6	6	6	4	4

Individual GHG Emission Estimates for Each Harmonization Step

Table S4. Independent and cumulative GHG emission estimates for each harmonization step. Bold numbers were harmonized for the respective harmonization step but italicized numbers were not.

Author	Year	Technology Type	As-Published Life Cycle GHG ($g\ CO_2eq/kWh$)	Harmonized by GWPs ($g\ CO_2eq/kWh$)	Harmonized by Lifetime ($g\ CO_2eq/kWh$)	Harmonized by Capacity Factor ($g\ CO_2eq/kWh$)	Harmonized by Syst. Boundary[a] ($g\ CO_2eq/kWh$)	Harmonized by All[b] ($g\ CO_2eq/kWh$)
Ardente	2008	onshore	15	*15*	**15**	**9.4**	*15*	**9.4**
Berry	1998	onshore	9.1	*9.1*	*9.1*	**9.4**	*9.1*	**9.4**
Chataignere	2003	onshore	7.5	*7.5*	**7.5**	**7.2**	**7.5**	**7.2**
Chataignere	2003	onshore	7.9	*7.9*	**7.9**	**9.0**	**7.9**	**9.0**
Chataignere	2003	offshore	9.2	*9.2*	**9.2**	**11**	**9.2**	**11**
Chataignere	2003	offshore	9.5	*9.5*	**9.5**	**11**	**9.5**	**11**
Chataignere	2003	offshore	9.8	*9.8*	**9.8**	**11**	**9.8**	**11**
Chataignere	2003	onshore	12	*12*	**12**	**12**	**12**	**12**
Crawford	2009	onshore	32	*32*	**32**	**35**	**32**	**36**
Crawford	2009	onshore	35	*35*	**35**	**39**	**35**	**40**
Dolan	2007	offshore	24	*24*	**24**	**18**	**24**	**18**
Dones	2005	onshore	11	*11*	*11*	**7.0**	*11*	**7.0**
Dones	2005	offshore	13	*13*	**13**	**10**	*13*	**10**
Dones	2007	onshore	9.6	*9.6*	*9.6*	**6.4**	**11**	**7.6**
Dones	2007	offshore	12	*12*	**12**	**9.2**	**13**	**9.7**
Dones	2007	onshore	14	*14*	*14*	**6.3**	**14**	**6.3**
DONG Energy	2008	offshore	8.1	*8.1*	**8.1**	**9.3**	**8.1**	**9.3**
ENEL SpA	2004	onshore	17	*17*	**17**	**10**	**17**	**10**
Eur. Comm.	1995	onshore	9.1	*9.1*	**9.1**	**9.1**	*9.1*	**9.1**
Frischknecht	1998	onshore	28	*28*	**28**	**8.5**	*28*	**8.5**
Hartmann	1997	onshore	14	**14**	**14**	**8.6**	*14*	**8.8**
Hartmann	1997	onshore	22	**22**	**22**	**14**	*22*	**14**
Hondo	2005	onshore	15	*15*	**27**	**10**	**15**	**18**
Hondo	2005	onshore	20	*20*	**27**	**14**	**21**	**18**
Hondo	2005	onshore	21	*21*	**40**	**14**	**21**	**27**
Hondo	2005	onshore	27	*27*	**27**	**18**	**27**	**18**
Hondo	2005	onshore	30	*30*	**40**	**20**	**30**	**27**
Hondo	2005	onshore	40	*40*	**40**	**27**	**40**	**27**
Hondo	2005	onshore	49	*49*	**27**	**33**	**49**	**18**
Hondo	2005	onshore	72	*72*	**40**	**48**	**72**	**27**
Jacobson	2009	onshore	2.8	*2.8*	**4.2**	**4.0**	*2.8*	**6.0**

Table S4. (continued)

Author	Year	Technology Type	As-Published Life Cycle GHG ($g\ CO_2eq/kWh$)	Harmonized by GWPs ($g\ CO_2eq/kWh$)	Harmonized by Lifetime ($g\ CO_2eq/kWh$)	Harmonized by Capacity Factor ($g\ CO_2eq/kWh$)	Harmonized by Syst. Boundary[a] ($g\ CO_2eq/kWh$)	Harmonized by All[b] ($g\ CO_2eq/kWh$)
Jacobson	2009	onshore	4.2	*4.2*	**4.2**	**6.0**	*4.2*	**6.0**
Jacobson	2009	onshore	7.4	*7.4*	**11**	**7.3**	*7.4*	**11**
Jacobson	2009	onshore	11	*11*	**11**	**11**	*11*	**11**
Jungbluth	2005	onshore	11	*11*	*11*	**7.3**	**12**	**8.6**
Jungbluth	2005	offshore	13	*13*	**13**	**9.8**	**13**	**10**
Khan	2005	onshore	17	*17*	**17**	*17*	*17*	**17**
Krewitt	1997	onshore	7.0	*7.0*	**7.0**	**5.7**	**8.8**	**5.7**
Kuemmel [c]	1997	mix	5.0	*5.0*	**6.3**	*5.0*	*5.0*	**6.3**
Kuemmel	1997	onshore	12	*12*	**12**	**9.1**	*12*	**9.1**
Lee [d]	2008	onshore	3.6	*3.6*	**3.6**	**4.0**	**5.0**	**5.2**
Lenzen	2004	onshore	2.0	*2.0*	**2.0**	**4.5**	**3.8**	**6.2**
Lenzen	2004	onshore	2.0	*2.0*	**2.0**	**4.8**	**3.8**	**6.5**
Lenzen	2004	onshore	2.0	*2.0*	**2.0**	**3.7**	**3.8**	**5.4**
Lenzen	2004	onshore	3.0	*3.0*	**3.0**	**6.8**	**4.8**	**8.5**
Lenzen	2004	onshore	3.0	*3.0*	**3.0**	**7.1**	**4.8**	**8.8**
Lenzen	2004	onshore	3.0	*3.0*	**3.0**	**5.5**	**4.8**	**7.2**
Lenzen	2004	onshore	3.0	*3.0*	**3.0**	**4.2**	**4.8**	**5.9**
Lenzen	2004	onshore	3.0	*3.0*	**3.0**	**4.6**	**4.8**	**6.3**
Lenzen	2004	onshore	4.0	*4.0*	**4.0**	**5.6**	**5.8**	**7.3**
Lenzen	2004	onshore	4.0	*4.0*	**4.0**	**6.1**	**5.8**	**7.8**
Lenzen	2004	onshore	8.0	*8.0*	**8.0**	**18**	**9.8**	**20**
Lenzen	2004	onshore	8.0	*8.0*	**8.0**	**19**	**9.8**	**21**
Lenzen	2004	onshore	10	*10*	**10**	**18**	**12**	**20**
Lenzen	2004	onshore	12	*12*	**12**	**18**	**14**	**20**
Lenzen	2004	onshore	13	*13*	**13**	**18**	**15**	**20**
Lenzen	2004	onshore	15	*15*	**15**	**34**	**17**	**36**
Lenzen	2004	onshore	16	*16*	**16**	**38**	**18**	**40**
Lenzen	2004	onshore	20	*20*	**20**	**37**	**22**	**39**
Lenzen	2004	onshore	26	*26*	**26**	**40**	**28**	**42**
Lenzen	2004	onshore	27	*27*	**27**	**38**	**29**	**39**
Lenzen	2004	onshore	45	*45*	**45**	**37**	**47**	**39**

Table S4. (continued)

Author	**Year**	**Technology Type**	**As-Published Life Cycle GHG ($g\ CO_2eq/kWh$)**	**Harmonized by GWPs ($g\ CO_2eq/kWh$)**	**Harmonized by Lifetime ($g\ CO_2eq/kWh$)**	**Harmonized by Capacity Factor ($g\ CO_2eq/kWh$)**	**Harmonized by Syst. Boundary[a] ($g\ CO_2eq/kWh$)**	**Harmonized by All[b] ($g\ CO_2eq/kWh$)**
Lenzen	2004	onshore	48	*48*	**48**	**42**	**50**	**43**
Lenzen	2004	onshore	61	*61*	**61**	**41**	**63**	**43**
Lenzen	2004	onshore	77	*77*	**77**	**43**	**79**	**45**
Lenzen	2004	onshore	81	*81*	**81**	**41**	**83**	**43**
Liberman	2003	onshore	13	*13*	*13*	*13*	**13**	**13**
Martínez	2009	onshore	6.2	*6.2*	**6.2**	**4.7**	**6.6**	**5.2**
Martínez	2009	onshore	6.6	*6.6*	**6.6**	**5.0**	**7.0**	**5.4**
Martínez	2009	onshore	9.3	*9.3*	**9.3**	**7.1**	**9.7**	**7.5**
McCulloch	2000	onshore	13	*13*	**16**	**8.7**	*13*	**11**
Nadal	1995	onshore	20	*20*	**20**	**13**	*20*	**13**
Pacca	2002	onshore	7.2	*7.2*	**7.2**	**5.7**	**9.0**	**7.4**
Pacca	2003	onshore	6.0	*6.0*	**15**	**4.7**	**7.8**	**13**
Pacca	2003	onshore	8.0	*8.0*	**15**	**6.3**	**9.8**	**13**
Pacca	2003	onshore	15	*15*	**15**	**12**	**17**	**13**
Pacca	2003	onshore	17	*17*	**15**	**13**	**19**	**13**
Pehnt	2006	offshore	9.0	**9.1**	*9.0*	*9.0*	*9.0*	**9.1**
Pehnt	2006	onshore	11	**11**	*11*	*11*	*11*	**11**
Pehnt	2008	offshore	22	*22*	*22*	*22*	**22**	**23**
Proops	1996	onshore	12	*12*	**12**	**12**	**12**	**12**
Proops	1996	onshore	23	*23*	**23**	**22**	**23**	**22**
Proops	1996	onshore	35	*35*	**35**	**33**	**36**	**35**
Rule	2009	onshore	3.0	*3.0*	*3.0*	**3.9**	*3.0*	**3.9**
Rydh	2004	onshore	7.2	*7.2*	**11**	**6.2**	**7.2**	**9.4**
Rydh	2004	onshore	7.3	*7.3*	**7.3**	**8.5**	**7.3**	**8.5**
Rydh	2004	onshore	11	*11*	**11**	**9.5**	**11**	**9.5**
Rydh	2004	onshore	11	*11*	**11**	**9.5**	**11**	**9.5**
SECDA	1994	onshore	11	*11*	**22**	**8.9**	**13**	**19**
Schleisner	2000	onshore	9.7	*9.7*	**9.7**	**8.1**	*9.7*	**8.1**
Schleisner	2000	offshore	17	*17*	**17**	**12**	*17*	**12**
Spitzley	2004	onshore	1.7	**1.7**	**2.6**	**2.1**	*1.7*	**3.0**
Spitzley	2004	onshore	2.5	**2.5**	**3.8**	**2.2**	*2.5*	**3.3**

Table S4. (continued)

Author	Year	Technology Type	As-Published Life Cycle GHG (g CO_2eq/kWh)	Harmonized by GWPs (g CO_2eq/kWh)	Harmonized by Lifetime (g CO_2eq/kWh)	Harmonized by Capacity Factor (g CO_2eq/kWh)	Harmonized by Syst. Boundary[a] (g CO_2eq/kWh)	Harmonized by All[b] (g CO_2eq/kWh)
Tremeac	2009	onshore	12	*12*	**12**	**12**	**12**	**12**
Tremeac	2009	onshore	16	*16*	**16**	**16**	**16**	**16**
Tremeac	2009	onshore	21	*21*	**21**	**21**	**21**	**21**
Uchiyama	1996	onshore	24	*24*	*24*	**16**	**24**	**16**
Uchiyama	1996	onshore	35	*35*	*35*	**23**	**35**	**24**
van de Vate	1996	onshore	11	*11*	**11**	**8.4**	*11*	**8.4**
Vattenfall [e]	2003	onshore	10	*10*	**13**	**7.2**	**10**	**9.0**
Vattenfall [f]	2010	mix	16	*16*	**16**	*16*	*16*	**16**
Vattenfall [f]	2010	mix	17	*17*	**17**	*17*	*17*	**17**
Vestas	2006a	onshore	7.0	*7.0*	**7.0**	**9.5**	*7.0*	**9.5**
Vestas	2006b	onshore	4.7	*4.7*	**4.7**	**8.5**	*4.7*	**8.5**
Vestas	2006b	offshore	5.3	*5.3*	**5.3**	**7.2**	*5.3*	**7.2**
Voorspools	2000	onshore	7.9	*7.9*	**7.9**	**9.0**	*7.9*	**9.0**
Voorspools	2000	onshore	9.2	*9.2*	**9.2**	**11**	*9.2*	**11**
Voorspools	2000	onshore	24	*24*	**24**	**9.1**	*24*	**9.1**
Voorspools	2000	onshore	27	*27*	**27**	**10**	*27*	**10**
Waters	1997	onshore	4.5	*4.5*	**5.7**	**3.5**	*4.5*	**4.4**
Weinzettel	2009	offshore	12	*12*	**12**	**15**	*12*	**15**
Weinzettel	2009	offshore	12	*12*	**12**	**16**	*12*	**16**
Weinzettel	2009	offshore	14	*14*	**14**	**10**	*14*	**10**
White	1998	onshore	8.9	*8.9*	**13**	**10**	**8.9**	**16**
White	1998	onshore	14	*14*	**18**	**12**	**14**	**14**
White	1998	onshore	20	*20*	**20**	**21**	**20**	**21**
White	2000	onshore	15	*15*	**19**	**12**	**15**	**15**
White	2006	onshore	14	*14*	**18**	**12**	**14**	**15**
White	2006	onshore	18	*18*	**27**	**17**	**18**	**26**
White	2006	onshore	34	*34*	**34**	**23**	**34**	**23**
Wibberly	2001	onshore	6.1	*6.1*	**9.2**	**4.3**	*6.1*	**6.4**
WEC	2004	onshore	8.2	*8.2*	*8.2*	**10**	*8.2*	**10**
WEC	2004	onshore	8.4	*8.4*	*8.4*	**6.4**	*8.4*	**6.4**
WEC	2004	onshore	12	*12*	*12*	**8.5**	*12*	**8.5**
WEC	2004	onshore	15	*15*	*15*	**12**	*15*	**12**
WEC	2004	offshore	22	*22*	*22*	**16**	*22*	**16**

[a] The “Harmonized by System Boundary” data were calculated using the non-harmonized add-on values (table S3) to show the effects of this independent harmonization step.

[b] The “Harmonized by All” data were calculated using the harmonized add-on values (table S3) for the harmonization of system boundary step, which are previously harmonized by GWPs, lifetime and capacity factor, to produce the cumulative harmonization results.

[c] This data point represents a mix of 1 MW onshore and 3 MW offshore turbines. As the proportion of onshore to offshore turbines in the mix is unknown, it could not be harmonized by capacity factor or system boundary.

[d] This data point represents a mix of (4) 660 kW, (4) 600 kW and (2) 1.75 MW turbines. Therefore, a capacity-weighted average capacity factor was used to allow for harmonization for this step.

[e] The capacity for this data point represents a weighted average of (1) 225 kW, (1) 500 kW, (7) 600 kW, and (1) 1.75 MW turbines. A capacity-weighted average capacity factor was used for harmonization of this step.

[f] The capacity for this data point represents a weighted average of the mix of (7) 600 kW, (4) 850 kW, (10) 1.5 MW, (63) 2.0 MW, (50) 2.3 MW, (30) 3 MW turbines. A capacity-weighted average capacity factor was used for harmonization of this step.

Overlay Plots of Successive Harmonization Steps

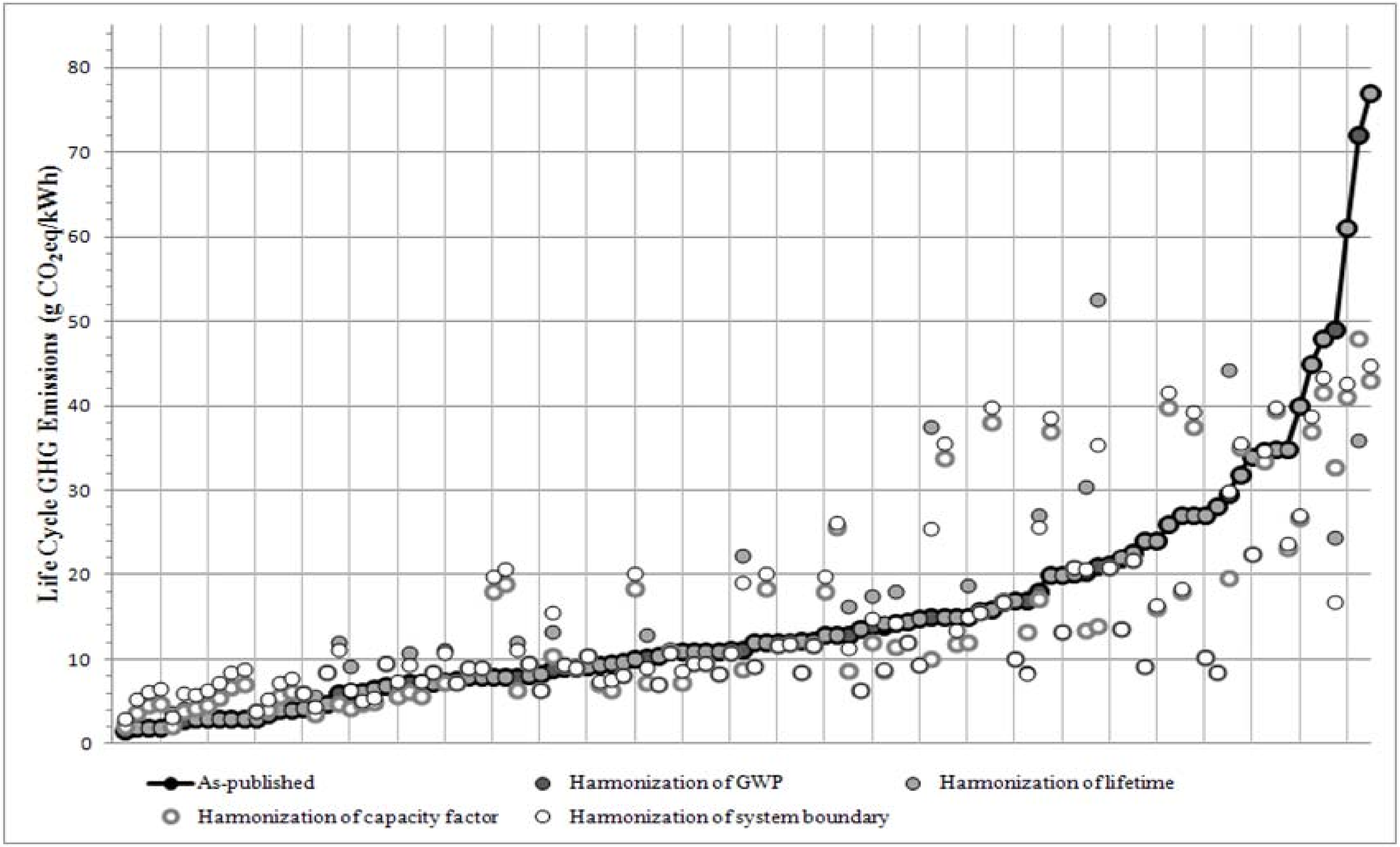

Figure S1. Succession of harmonization steps for onshore wind starting from published values and performed in the following order: harmonization of global warming potentials (GWPs), harmonization of lifetime, harmonization of capacity factor, and harmonization of system boundary. Each step builds upon the previous step.

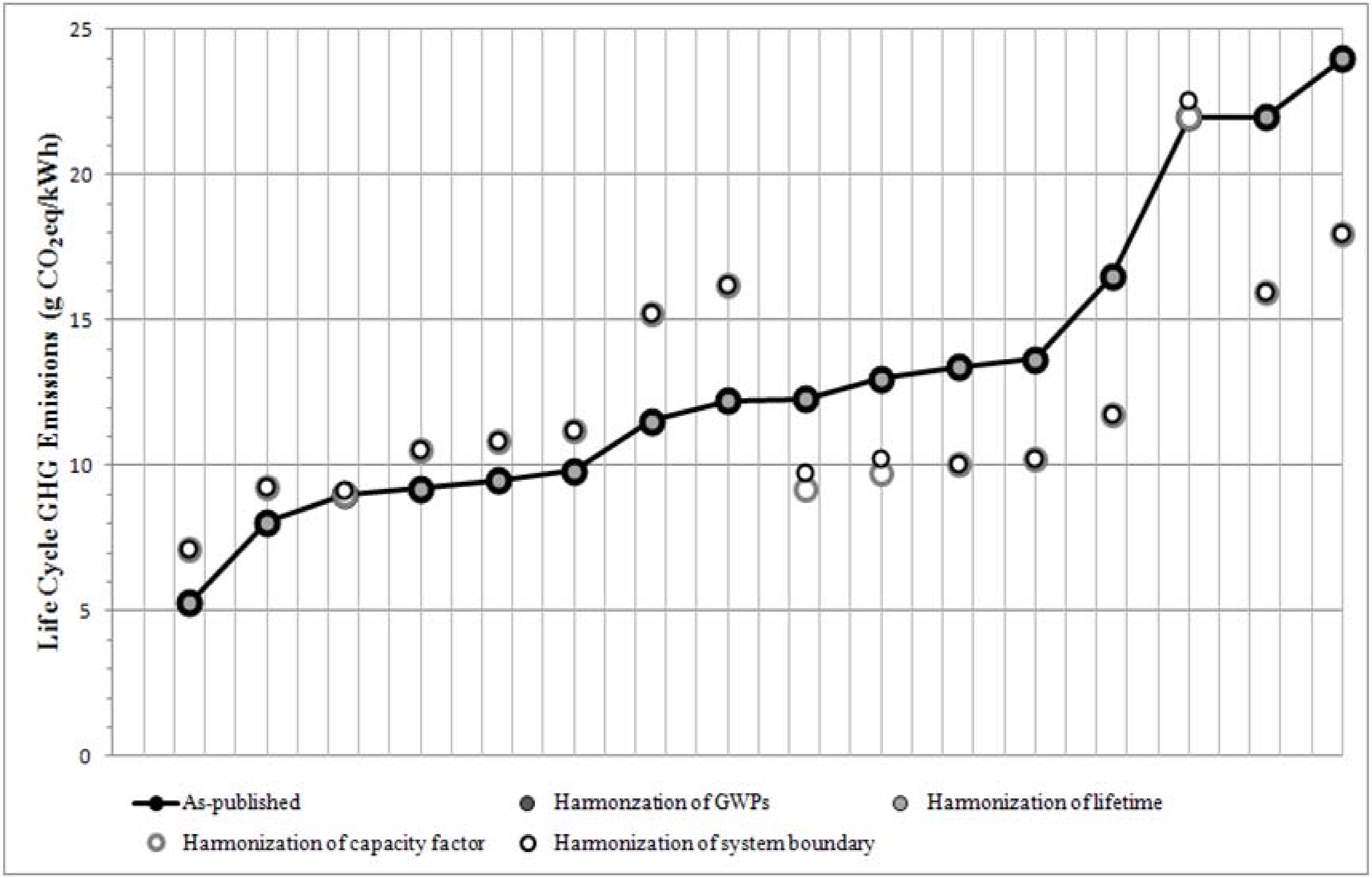

Figure S2. Succession of harmonization steps for offshore wind starting from published values and performed in the following order: harmonization of GWP, harmonization of lifetime, harmonization of capacity factor, and harmonization of system boundary. Each step builds upon the previous step.

Rationale for System Boundary Harmonization Approach

An alternative method for harmonizing by system boundary would have been to use a proportional multiplier, rather than an add-on value, for the ongoing and downstream stages based on the respective mean proportions of the total life cycle GHG emissions that those stages comprise. However, there are two reasons why the add-on value is preferable over the proportional multiplier for the case of wind power. First, there are fewer publications that provide disaggregated emissions data for all three life cycle stages than the number of papers that provide estimates for one, two, or all three life cycle stages, so the add-on values have a stronger empirical foundation than the proportional multipliers would have had. Second, using a proportional multiplier assumes that the ongoing and downstream life cycle stages are proportional to the upstream life cycle stage. However, in the case of wind power, the upstream emissions are largely a result of materials manufacture, while the ongoing and downstream emissions are largely a result of fuel combustion for transportation to and from the turbines for maintenance and for construction equipment used during decommissioning. Therefore, since the assumption that ongoing and downstream emissions are proportional to upstream emissions is questionable, the add-on method was deemed the more suitable option.

References Cited in the text:

Whitaker M, Heath GA, O'Donoughue P, Vorum M. 2011. (submitted) Life Cycle Greenhouse Gas Emissions of Coal-Fired Electricity Generation: Systematic Review and Harmonization. Journal of Industrial Ecology.