Data on atmospheric emissions from WP3

Table 1. Current technologies

Current	Direct emissions (g/kWh)								Indirect emissions (g/kW)							
	CO_2	SO_2	NOx	PM_{10}	NMVOC	CH_4	N_2O	C_{14}	CO_2	SO_2	NOx	PM_{10}	NMVOC	CH_4	N_2O	C_{14}
3.1.1 COAL																
Lignite, IGCC	886.2	0.779	0.483	0.044	0.013	0.154	0.027	0.051	3.076	0.005	0.009	0.027	0.001	0.003	0	0.006
Lignite, ST	901.5	0.651	0.674	0.097	0.018	0.016	0.028	0.012	1.135	0.004	0.005	0.004	0.001	0.004	0	0.011
Coal condensing	854.9 (1)	0.270 (1)	0.360 (1)	n.d.	n.d.	n.d.	n.d.	n.d.	(1)	(1)	(1)	n.d.	n.d.	n.d.	n.d.	n.d.
3.1.2 OIL & GAS																
CCGT	348.8	0	0.176	8E-04	0	0	0	0	3.38	0	0.002	8E-06	0	0	0	0
3.1.3 CHP																
Small-scale	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Large-scale	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.1.4 CO_2 CS																
Natural gas																
Lignite																
3.2.1 FISSION																
Nuclear fission * kBq/kWh				2E-05 (1)	3E-04 (1)	6E-04 (1)	9E-06 (1)	0.02* (1)	0.3	0.001	0.001	(1)	(1)	(1)	(1)	(1)
3.2.2 FUSION																
Nuclear fusion																
3.3.1 WIND																
Wind turbine									6.25	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.2 PV																
Crystalline * kBq/kWh									48.3	0.01	0.095	0.006	0.016	0.114	4E-04	0.416*
Thin-film amorphous									41.9	0.009	0.091	0.002	0.011	0.077	4E-04	0.197*

* kBq/kWh																
Thin-film CIGS * kBq/kWh									42.5	0.006	0.005	0.004	0.011	0.083	2E-04	3.00
3.3.3 BIOMASS																
Biomass gasification	11.5 (2)	0.265 (2)	0.494 (2)	0.001 (2)	0.522 (2)	0 (2)	0 (2)	n.d. (2)	34.4 (2)	0.302 (2)	0.192 (2)	0.003 (2)	0.073 (2)	0.005 (2)	0.010 (2)	n.d. (2)
3.3.4 HYDRO																
Large scale						0.006 (1)			2.778	0.001	0.007	n.d.	n.d.	(1)	n.d.	n.d.
Small scale									n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.5 GEO																
Conventional * H_2S	372	3.65 *			n.d.	n.d.			n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Binary cycle									n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.6 FUEL CELLS																
PEMFC	601 (1)	0.3 (1)	0.088 (1)	0.011 (1)	2E-06 (1)	0.64 (1)	6E-04 (1)	n.d.	(1)	(1)	(1)	(1)	(1)	(1)	(1)	n.d.
AFC	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
PAFC	649 (1)	0.38 (1)	0.006 (1)	n.d.	0.002 (1)	0 (1)	n.d.	n.d.	(1)	(1)	(1)	n.d.	(1)	(1)	n.d.	n.d.
MCFC	481 (1)	0.32 (1)	0.319 (1)	0.005 (1)	n.d.	0.006 (1)	n.d.	n.d.	(1)	(1)	(1)	(1)	n.d.	(1)	n.d.	n.d.
SOFC	511 (1)	0.25 (1)	0.032	0	7E-05 (1)	0.238	n.d.	n.d.	(1)	(1)	0.012	0.008	(1)	0	n.d.	n.d.
3.3.7 HYDROGEN																
Hydrogen economy																
3.3.8 STORAGE																
Electricity storage	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.9 MARINE																
Wave									18	0.16	0.07	n.d.	n.d.	n.d.	n.d.	n.d.
Tidal									12	0.08	0.03	n.d.	n.d.	n.d.	n.d.	n.d.

Shadow cells mean ‘not applicable’
n.d.: no data
(1) direct and indirect emissions
(2) data on materials for construction available

Table 2. Advanced technologies- 2010

Advanced	Direct emissions (k/kWh)								Indirect emissions (k/kW)							
	CO_2	SO_2	NOx	PM_{10}	NMVOC	CH_4	N_2O	C_{14}	CO_2	SO_2	NOx	PM_{10}	NMVOC	CH_4	N_2O	C_{14}
3.1.1 COAL FIRED																
Lignite, IGCC	841.3	0.74	0.461	0.041	0.013	0.147	0.026	0.049	3.076	0.005	0.009	0.027	0.001	0.003	0	0.006
Lignite, ST	883.5	0.644	0.667	0.097	0.018	0.016	0.028	0.012	1.081	0.004	0.005	0.004	0.001	0.003	0	0.011
Pulverised Coal	854.9 (1)	0.270 (1)	0.360 (1)	n.d.	n.d.	n.d.	n.d.	n.d.	(1)	(1)	(1)	n.d.	n.d.	n.d.	n.d.	n.d.
3.1.2 OIL & GAS																
CCGT	343.2	0	0.173	8E-04	0	0	0	0	3.32	0	0.002	8E-06	0	0	0	0
3.1.3 CHP																
Small-scale	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Large-scale	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.1.4 CO_2 CS																
Natural gas	44.90	0.208	0.454	0.008	0.150	1.010	0.011	0.033	0.215	0.001	0.001	0.002	0	0	0	0.001
Lignite	139.7	0.823	0.520	0.109	0.016	0.046	0.031	0.051	3.252	0.005	0.010	0.028	0.001	0.004	0	0.006
3.2.1 FISSION																
Nuclear fission				n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.2.2 FUSION																
Nuclear fusion	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.1 WIND																
Wind turbine									n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.2 PV																
?????									41.21	0.008	0.075	0.005	0.013	0.095	3E-04	0.343
3.3.3 BIOMASS																
Biomass gasification	11	n.d.	n.d.	0	n.d.	0	0	n.d.	34.4	0.302	0.192	0.003	0.073	0.005	0.010	n.d.
3.3.4 HYDRO																
Large scale						0.006 (1)			2.778	0.001	0.007	n.d.	n.d.	(1)	n.d.	n.d.

Small scale									n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.5 GEO																
Conventional	372	3.65 *			n.d.	n.d.			n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Binary cycle									n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.6 FUEL CELLS*																
PEMFC	601 (1)	0.3 (1)	0.088 (1)	0.011 (1)	2E-06 (1)	0.64 (1)	6E-04 (1)	n.d.	(1)	(1)	(1)	(1)	(1)	(1)	(1)	n.d.
AFC	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
PAFC	649 (1)	0.38 (1)	0.006 (1)	n.d.	0.002 (1)	0 (1)	n.d.	n.d.	(1)	(1)	(1)	n.d.	(1)	(1)	n.d.	n.d.
MCFC	481 (1)	0.32 (1)	0.319 (1)	0.005 (1)	n.d.	0.006 (1)	n.d.	n.d.	(1)	(1)	(1)	(1)	n.d.	(1)	n.d.	n.d.
SOFC	511 (1)	0.25 (1)	0.032	0	7E-05 (1)	0.238	n.d.	n.d.	(1)	(1)	0.012	0.008	(1)	0	n.d.	n.d.
3.3.7 HYDROGEN																
Hydrogen economy	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.8 STORAGE																
Electricity storage	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.9 MARINE																
Marine									18	0.16	0.07	n.d.	n.d.	n.d.	n.d.	n.d.
Tidal									12	0.08	0.03	n.d.	n.d.	n.d.	n.d.	n.d.

Shadow cells mean 'not applicable'
n.d.: no data
(1) direct and indirect emissions
* Data for current and advanced FC are the same

Table 3. Advanced technologies- 2020

Advanced	Direct emissions (k/kWh)								Indirect emissions (k/kW)							
	CO_2	SO_2	NOx	PM_{10}	NMVOC	CH_4	N_2O	C_{14}	CO_2	SO_2	NOx	PM_{10}	NMVOC	CH_4	N_2O	C_{14}
3.1.1 COAL FIRED																
Lignite, IGCC	793.1	0.699	0.436	0.039	0.013	0.140	0.025	0.048	3.076	0.005	0.009	0.027	0.001	0.003	0	0.006
Lignite, ST	802.5	0.579	0.603	0.093	0.017	0.015	0.025	0.012	0.974	0.004	0.005	0.003	0.001	0.003	0	0.01
Pulverised Coal	854.9 (1)	0.270 (1)	0.360 (1)	n.d.	n.d.	n.d.	n.d.	n.d.	(1)	(1)	(1)	n.d.	n.d.	n.d.	n.d.	n.d.
3.1.2 OIL & GAS																
CCGT	332.3	0	0.168	8E-04	0	0	0	0	3.22	0	0.002	8E-06	0	0	0	0
3.1.3 CHP																
Small-scale	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Large-scale	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.1.4 CO_2 CS																
Natural gas	44.18	0.202	0.44	0.008	0.146	0.982	0.011	0.032	0.215	0.001	0.001	0.002	0	0	0	0.001
Lignite	130.9	0.771	0.488	0.106	0.016	0.043	0.028	0.049	3.252	0.005	0.01	0.028	0.001	0.004	0	0.006
3.2.1 FISSION																
Nuclear fission				n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.2.2 FUSION																
Nuclear fusion	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.1 WIND																
Wind turbine									n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.2 PV																
?????									31.88	0.006	0.044	0.003	0.010	0.070	2E-04	0.249
3.3.3 BIOMASS																
Biomass gasification	10	n.d.	n.d.	0	n.d.	0	0	n.d.	34.4	0.302	0.192	0.003	0.073	0.005	0.010	n.d.
3.3.4 HYDRO																
Large scale						0.006 (1)			2.778	0.001	0.007	n.d.	n.d.	(1)	n.d.	n.d.

Small scale									n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.5 GEO																
Conventional	372	3.65 *			n.d.	n.d.			n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Binary cycle									n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.6 FUEL CELLS*																
PEMFC	601 (1)	0.3 (1)	0.088 (1)	0.011 (1)	2E-06 (1)	0.64 (1)	6E-04 (1)	n.d.	(1)	(1)	(1)	(1)	(1)	(1)	(1)	n.d.
AFC	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
PAFC	649 (1)	0.38 (1)	0.006 (1)	n.d.	0.002 (1)	0 (1)	n.d.	n.d.	(1)	(1)	(1)	n.d.	(1)	(1)	n.d.	n.d.
MCFC	481 (1)	0.32 (1)	0.319 (1)	0.005 (1)	n.d.	0.006 (1)	n.d.	n.d.	(1)	(1)	(1)	(1)	n.d.	(1)	n.d.	n.d.
SOFC	511 (1)	0.25 (1)	0.032	0	7E-05 (1)	0.238	n.d.	n.d.	(1)	(1)	0.012	0.008	(1)	0	n.d.	n.d.
3.3.7 HYDROGEN																
Hydrogen economy	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.8 STORAGE																
Electricity storage	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.9 MARINE																
Marine									18	0.16	0.07	n.d.	n.d.	n.d.	n.d.	n.d.
Tidal									12	0.08	0.03	n.d.	n.d.	n.d.	n.d.	n.d.

Shadow cells mean 'not applicable'
n.d.: no data
(1) direct and indirect emissions
* Data for current and advanced FC are the same

Table 4. Advanced technologies- 2030

Advanced	Direct emissions (k/kWh)								Indirect emissions (k/kW)							
	CO_2	SO_2	NOx	PM_{10}	NMVOC	CH_4	N_2O	C_{14}	CO_2	SO_2	NOx	PM_{10}	NMVOC	CH_4	N_2O	C_{14}
3.1.1 COAL FIRED																
Lignite, IGCC	785.6	0.693	0.432	0.039	0.013	0.138	0.025	0.048	3.076	0.005	0.009	0.027	0.001	0.003	0	0.006
Lignite, ST	802.5	0.579	0.603	0.093	0.017	0.015	0.025	0.012	0.974	0.004	0.005	0.003	0.001	0.003	0	0.01
Pulverised Coal	854.9 (1)	0.270 (1)	0.360 (1)	n.d.	n.d.	n.d.	n.d.	n.d.	(1)	(1)	(1)	n.d.	n.d.	n.d.	n.d.	n.d.
3.1.2 OIL & GAS																
CCGT	321.8	0	0.162	8E-04	0	0	0	0	3.11	0	0.002	8E-06	0	0	0	0
3.1.3 CHP																
Small-scale	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Large-scale	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.1.4 CO_2 CS																
Natural gas	43.24	0.2	0.437	0.008	0.144	0.970	0.011	0.032	0.215	0.001	0.001	0.002	0	0	0	0.001
Lignite	127.3	0.749	0.477	0.103	0.016	0.042	0.027	0.047	3.252	0.005	0.010	0.028	0.001	0.004	0	0.006
3.2.1 FISSION																
Nuclear fission				n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.2.2 FUSION																
Nuclear fusion	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.1 WIND																
Wind turbine									n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.2 PV																
?????									25.75	0.004	0.019	0.002	0.007	0.052	2E-04	0.18
3.3.3 BIOMASS																
Biomass gasification	10	n.d.	n.d.	0	n.d.	0	0	n.d.	34.4	0.302	0.192	0.003	0.073	0.005	0.010	n.d.
3.3.4 HYDRO																
Large scale						0.006 (1)			2.778	0.001	0.007	n.d.	n.d.	(1)	n.d.	n.d.

Small scale									n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.5 GEO																
Conventional	372	3.65 *			n.d.	n.d.			n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Binary cycle									n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.6 FUEL CELLS*																
PEMFC	601 (1)	0.3 (1)	0.088 (1)	0.011 (1)	2E-06 (1)	0.64 (1)	6E-04 (1)	n.d.	(1)	(1)	(1)	(1)	(1)	(1)	(1)	n.d.
AFC	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
PAFC	649 (1)	0.38 (1)	0.006 (1)	n.d.	0.002 (1)	0 (1)	n.d.	n.d.	(1)	(1)	(1)	n.d.	(1)	(1)	n.d.	n.d.
MCFC	481 (1)	0.32 (1)	0.319 (1)	0.005 (1)	n.d.	0.006 (1)	n.d.	n.d.	(1)	(1)	(1)	(1)	n.d.	(1)	n.d.	n.d.
SOFC	511 (1)	0.25 (1)	0.032	0	7E-05 (1)	0.238	n.d.	n.d.	(1)	(1)	0.012	0.008	(1)	0	n.d.	n.d.
3.3.7 HYDROGEN																
Hydrogen economy	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.8 STORAGE																
Electricity storage	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3.3.9 MARINE																
Marine									18	0.16	0.07	n.d.	n.d.	n.d.	n.d.	n.d.
Tidal									12	0.08	0.03	n.d.	n.d.	n.d.	n.d.	n.d.

Shadow cells mean 'not applicable'
n.d.: no data
(1) direct and indirect emissions
* Data for current and advanced FC are the same