Training Workshop

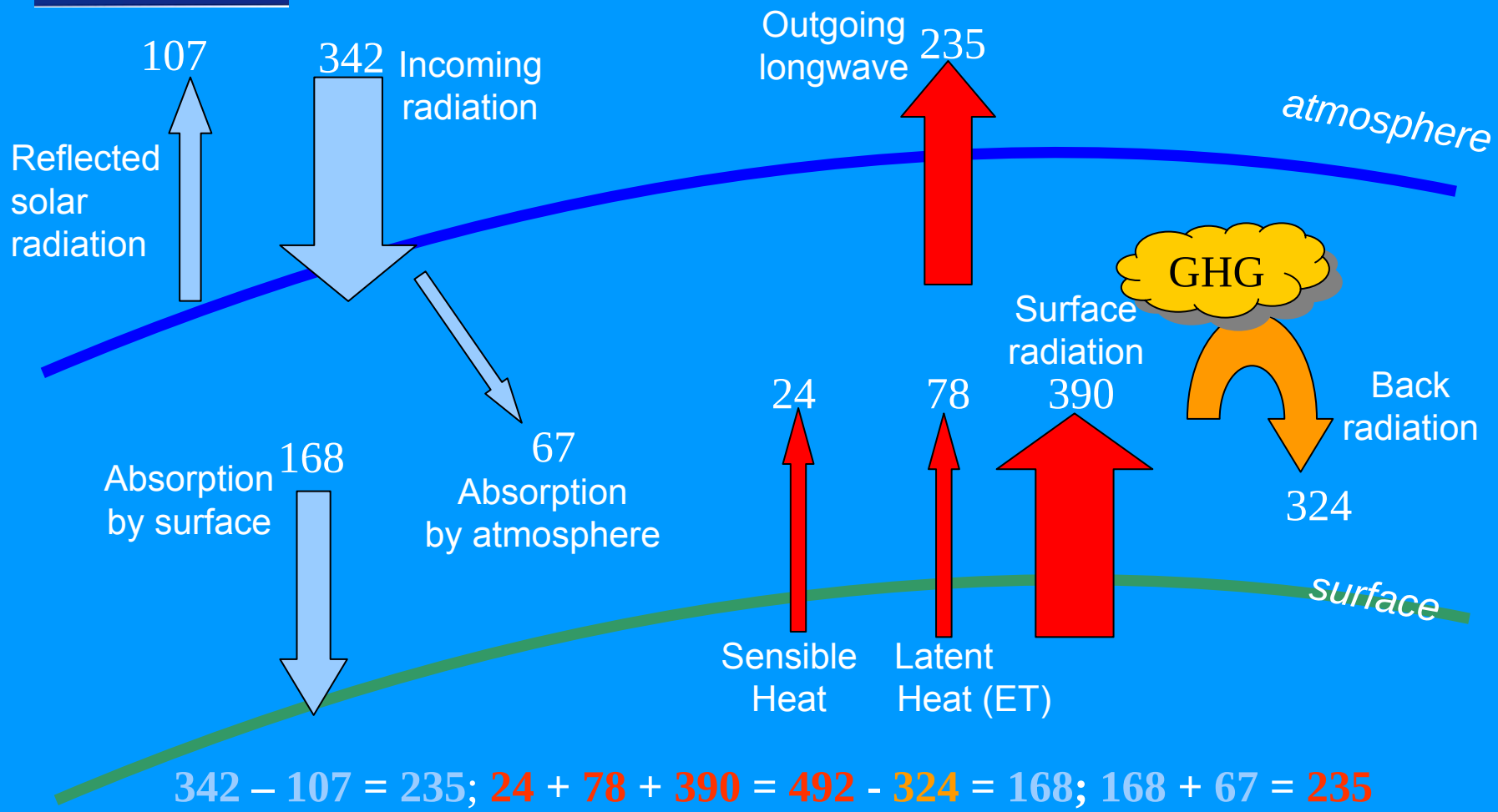
Development of Baselines

Johannes Laubach
laubachj@fichtner.de

Table of Contents

1. Greenhouse Gases (GHGs) and Global Warming Potential (GWP)

Greenhouse Gases (GHGs)



342 – 107 = 235; 24 + 78 + 390 = 492 - 324 = 168; 168 + 67 = 235

Balance of GHG Radiation (W m^{-2})

Global Warming Potential (GWP)

Global Warming Potential: "A measure of the relative radiative effect of a given substance compared to CO_2, integrated over a chosen time horizon. „ Unit related to mass of substance in [kg] or [t]

Table 1. GWP of Greenhouse Gases on a 100 Year Horizon used in UK NIR, IPCC (1996)

Gas	GWP
Carbon Dioxide	1
Methane	21
Nitrous Oxide	310
HFCs	140-11700
PFCs	6500-9200
SF6	23900

List of GHGs with GWP (I)

Species	Chemical Formula	GWP (100 year time horizon)
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide	N_2O	310
HFC-23	CHF_3	11,700
HFC-32	CH_2F_2	650
HFC-41	CH_3F	150
HFC-43-10mee	$C_5H_2F_{10}$	1,300
HFC-125	C_2HF_5	2,800
HFC-134	$C_2H_2F_4$	1,000
HFC-134a	CH_2FCF_3	1,300
HFC-152a	$C_2H_4F_2$	140
HFC-143	$C_2H_3F_3$	300
HFC-143a	$C_2H_3F_3$	3,800
HFC-227ea	C_3HF_7	2,900

List of GHGs with GWP (II)

Species	Chemical Formula	GWP (100 year time horizon)
HFC-236fa	$C_3H_2F_6$	6,300
HFC-245ca	$C_3H_3F_5$	560
Chloroform	$CHCl_3$	4
Methylene chloride	CH_2Cl_2	9
Perfluoromethane	CF_4	6,500
Perfluoroethane	C_2F_6	9,200
Perfluoropropane	C_3F_8	7,000
Perfluorobutane	C_4F_{10}	7,000
Perfluoropentane	C_5F_{12}	7,500
Perfluorohexane	C_6F_{14}	7,400
Perfluorocyclobutane	$c\text{-}C_4F_8$	8,700
Sulphur hexafluoride	SF_6	23,900

2. Calculation of GHG Emissions

CO_2 Emissions of Fossil Fuel Combustion

An inevitable fate of combustion of fossil fuels are CO_2 emissions

		ΔH [kJ/mol]
Coal	$C + O_2 \longrightarrow CO_2$	- 393.5
Heavy Oil	$C_{20}H_{42} + 30.5O_2 \longrightarrow 20CO_2 + 21\ H_2O$	- 13 300
Natural Gas	$CH_4 + 2O_2 \longrightarrow CO_2 + 21\ H_2O$	- 890.3

Molecular Weights

C= 12 g/mol

O_2 = 2*16 g/mol

CO_2 = 12 g/mol + 2*16 g/mol = 44 g/mol

CO_2 Emission Factors

- Burning of 1 mol Coal releases 1 mol CO_2 to the athmosphere!

  ΔH= -393.5 *10^9 TJ / mol

  Emission Factor (Coal) = $\frac{1*44*10^{-6} ton/mol}{393.5*10^{-9} TJ/mol}$ = 111.8 t CO_2/ TJ

- Burning of 1 mol Heavy Oil releases 20 mol CO_2 to the athmosphere!

  ΔH= - 13 300 *10^9 TJ / mol

  Emission Factor (Heavy Oil) = $\frac{20*44*10^{-6} ton/mol}{13300*10^{-9} TJ/mol}$ = 66.1 t CO_2/ TJ

- Burning of 1 mol Natural Gas releases 1mol CO_2 to the athmosphere!

  ΔH= - 890.3 *10^9 TJ / mol

  Emission Factor (Natural Gas) = $\frac{1*44*10^{-6} ton/mol}{890.3*10^{-9} TJ/mol}$ = 48.4 t CO_2/ TJ

Carbon Content of Fuels

1 mol **Coal** (C) → **Carbon Content** = $\frac{12gC}{12gC} * 100$ = **100%**

1 mol **Heavy Oil** ($C_{20}H_{42}$) → **Carbon Content** = $\frac{320gC}{320gC + 42gH} * 100$ = 88%

1 mol **Natural Gas** (CH_4) → **Carbon Content** = $\frac{12gC}{12gC + 4gH} * 100$ = **79%**

Calculating CO_2 Emissions

Table.2 Calculating CO_2 emissions from the combustion of standard fuels

		Step 1		Step 2		Step 3	
		A	B	C	D	E	F
		Quantity of fuel burned	Unit used to measure quantitiy of fuel use	CO_2 emission factor	Unit of CO_2 emission factor	CO_2 emissions in kg	CO_2 emissions in metric tons
						E = A * B	F = E / 1'000
Example: Source 1	Natural gas	1000,00	GJ	56,10	kg CO2 / GJ	56.100	
Source description	**Fuel type**						
						0,00	0,00
						0,00	0,00
						0,00	0,00
						0,00	0,00
						0,00	0,00
						0,00	0,00

Calculating CO_2 Emission Factors

	A	B	C
	Net Calorific Value	**Carbon Content**	**Emission Factor**
			C = B * 3'664 / A
	GJ / metric tons	(% w/w)	kg CO2 / GJ
		This should be entered as a fraction, i.e. 0 > x > 1	
Fuel Type			
			0,00
			0,00
			0,00
			0,00
			0,00

Typical CO_2 Emission Factors (I)

Fuel type	kg CO_2 / GJ fuel used (based on lower heating values)	kg CO_2 / MWh fuel used (based on lower heating	kg CO_2 / GJ fuel used (based on higher heating	kg CO_2 / MWh fuel used (based on higher heating	kg CO2 / metric tons fuel used	kg CO_2 / litres fuel used	kg CO_2 / standard cubic meters fuel used
Liquid fossil							
Gasoline / petrol	69,25	249,28	67,25	242,15	3135 (UK DETR)	2,34	
Kerosene	71,45	257,20	68,59	246,96	3150 (UK DETR)	2,58	
Jet Fuel	70.72 (EIA)	254.64 (EIA)	67,18	241,91		2,53	
Aviation gasoline	69.11 (EIA)	248.86 (EIA)	65,66	236,42		2,20	
Distillate fuel (No.1, No.2, No.4 fuel oil and diesel)	74,01	266,41	69,38	249,83	3142 (UK DETR)	2,68	
Residual fuel oil (No.5, No.6 fuel oil)	77,30	278,26	74,77	269,22	3117 (UK DETR)	3,12	
LPG	63,20	227,50	59,78	215,26		1,54	
Propane	62.99 (EIA)	226.8 (EIA)	59,84	215,46		1,52	
Gaseous fossil							
Natural gas (dry)	56,06	201,80	50,34	181,26			1,93
Solid fossil							
Anthracite	98,30	353,85	97,77	352,05	1926,04		
Bituminous coal	94,53	340,28	88,27	317,82	2465,61		
Sub-bituminous coal	96,00	345,57	91,45	329,28	1857,91		
Lignite	101,12	364,00	92,61	333,45	1395,83		
Peat	105,89	381,26	100.6 (IPCC)	362.2 (IPCC)			

Source: http://www.ghgprotocol.org/standard/tools.htm

Typical Emission Factors (II)

Fuel type	kg CO_2 / GJ fuel used (based on lower heating values)	kg CO_2 / MWh fuel used (based on lower heating values)	kg CO_2 / GJ fuel used (based on higher heating values)	kg CO_2 / MWh fuel used (based on higher heating values)	kg CO2 / metric tons fuel used	kg CO_2 / litres fuel used	kg CO_2 / standard cubic meters fuel used
Other fossil fuels							
Petroleum coke	100,76	362,71	96,80	348,53	3384,37	3,88	
Coke oven / gas coke	108,09	389,18	102.68 (IPCC)	369.72 (IPCC)			
Alternative fossil fuels							
Lubricants	73,28	263,86	69.62 (IPCC)	250.67 (IPCC)	2947 (UK DETR)		
Synfuel	*79,90*	*287,68*	*75,90*	*273,30*			
Chlorinated solvents	*75,10*	*256,31*	*71,34*	*243,49*			
Tar	*79,90*	*287,68*	*75,90*	*273,30*			
Sludges	*79,90*	*287,68*	*75,90*	*273,30*			
Liquid wastes	*79,90*	*287,68*	*75,90*	*273,30*			
Pitch	*79,90*	*287,68*	*75,90*	*273,30*			
Solvents	*75,10*	*256,31*	*71,34*	*243,49*			
Saw dust impregnated	*75,10*	*256,31*	*71,34*	*243,49*			
Distillation residues	*79,90*	*287,68*	*75,90*	*273,30*			
Plastics	*75,10*	*256,31*	*71,34*	*243,49*			
Tires and tire derived fuel	85,78	308,86	81,49	293,41	3080,03		
Municipal solid waste*	557 kg CO_2/wet tonne (Derived from IPCC) Good Practice Guidance)*						
Biofuels							
Wood and wood waste	100.44 (EIA)	361.67 (EIA)	95,42	343,58	1906,97		

Source: http://www.ghgprotocol.org/standard/tools.htm

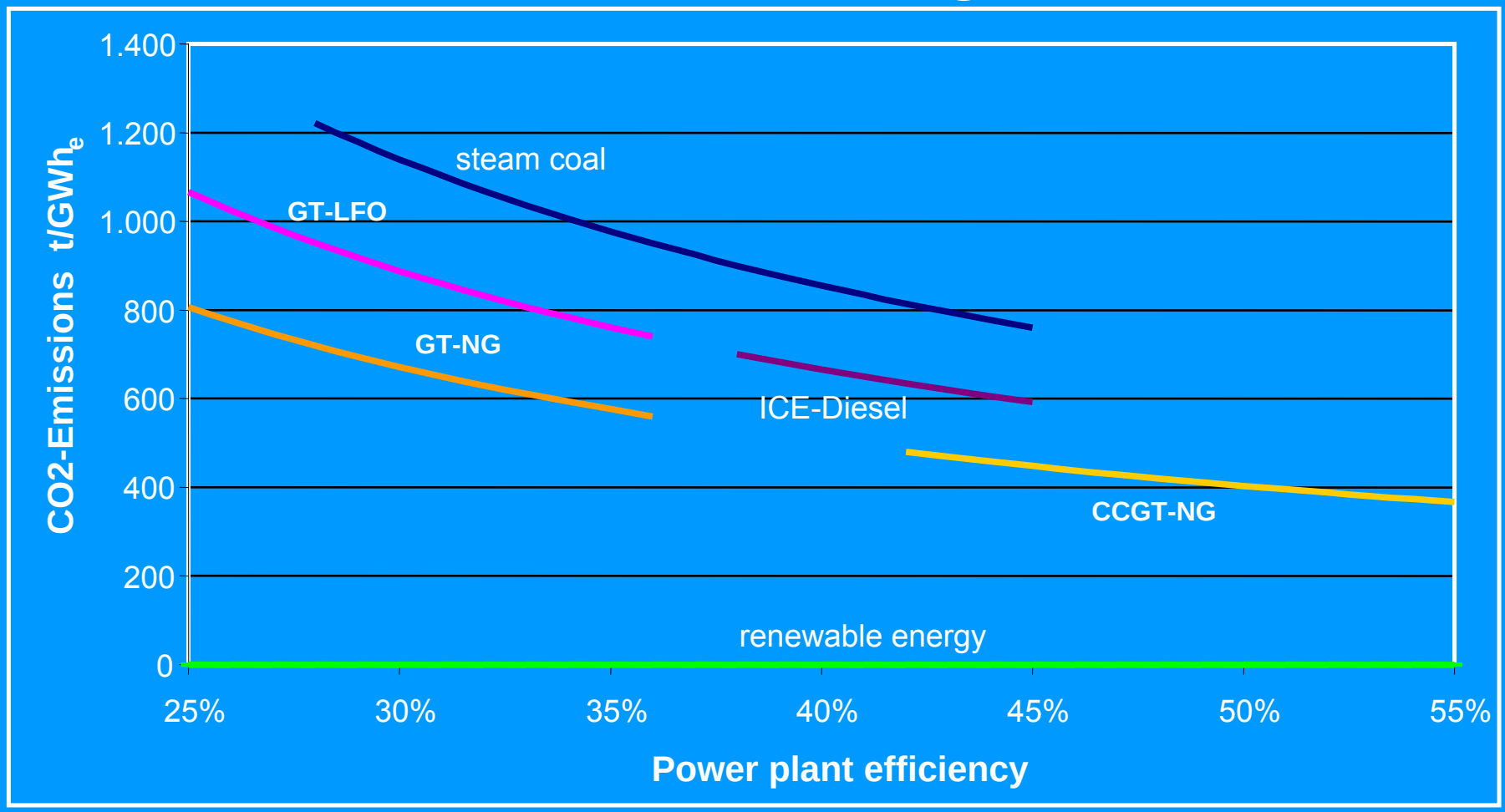
Emission Factors for Selected Fuels

Fuel	t CO_2/TJ_{NCV}	t CO_2/GWh_{NCV}
Lignite	111	400
Hard coal	95	342
Heavy fuel oil (HFO)	78	281
Light fuel oil (LFO)	74	266
Natural gas (NG)	56	202
Renewable energies	0	0

Source: Umwelt Bundesamt, Germany

$$\text{El. emissions } t\,CO2/GW_eh = \frac{\text{fuel emission factor in t CO2/GWh}_{NCV}}{\text{average efficiency of power plant (-)}}$$

CO_2 Emissions per GWh_e of Condensing PPs



CO_2/kWh Emission Coefficients for Power Plants

	Emission coefficient kgCO2/kWh	Fuel	Efficiency
Single cycle combustion turbines	0,631	Nat. gas	32,0%
	0,870	Fuel oil	32,0%
Combined cycle turbines	0,404	Nat. gas	50,0%
	0,533	Diesel	50,0%
	0,557	Fuel oil	50,0%
Steam turbines	0,577	Nat. gas	35,0%
	0,762	Diesel	35,0%
	0,796	Fuel oil	35,0%
	0,973	Coal	35,0%
Diesel engine	0,808	Diesel	33,0%
	0,844	Fuel oil	33,0%

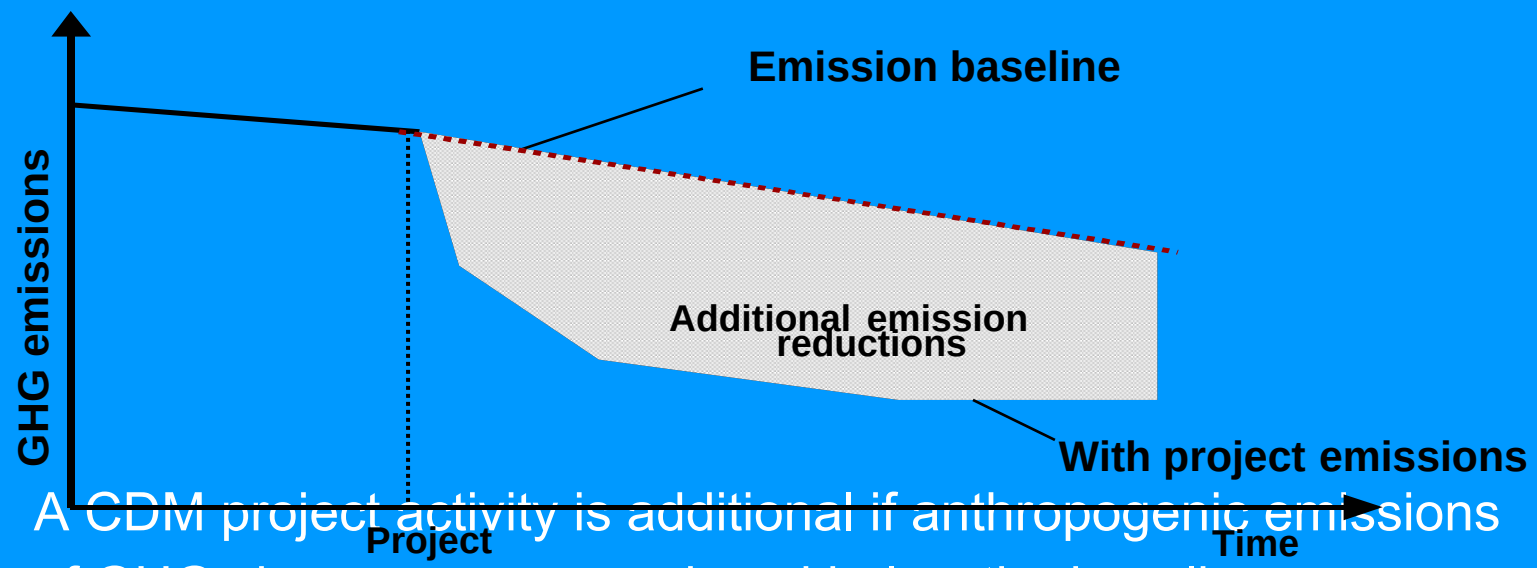
The emission coefficient is calculated in the following way:

kg CO_2/kWh = kgCO_2 / GJ / efficiency * 3,6 / 1000

3. Baseline Definition

Definition of Baseline

- The scenario that represents the anthropogenic emissions by sources of GHGs that would occur in the absence of the proposed project activity, i.e **“business as usual”**



- A CDM project activity is additional if anthropogenic emissions of GHGs by sources are reduced below the baseline.

Criteria for Baselines

- Regardless of chosen methodology a baseline must take into consideration
  - Approved and new methodologies (Executive Board)
  - Established in a transparent and conservative manner
  - Take into account national and/or sectoral policies and programs (current & future)
  - Developed on a project-specific basis
  - Justification of the appropriateness of baselines choice
  - Timeframe of 7 years with option of two renewals (21 years) or 10 years with no renewals

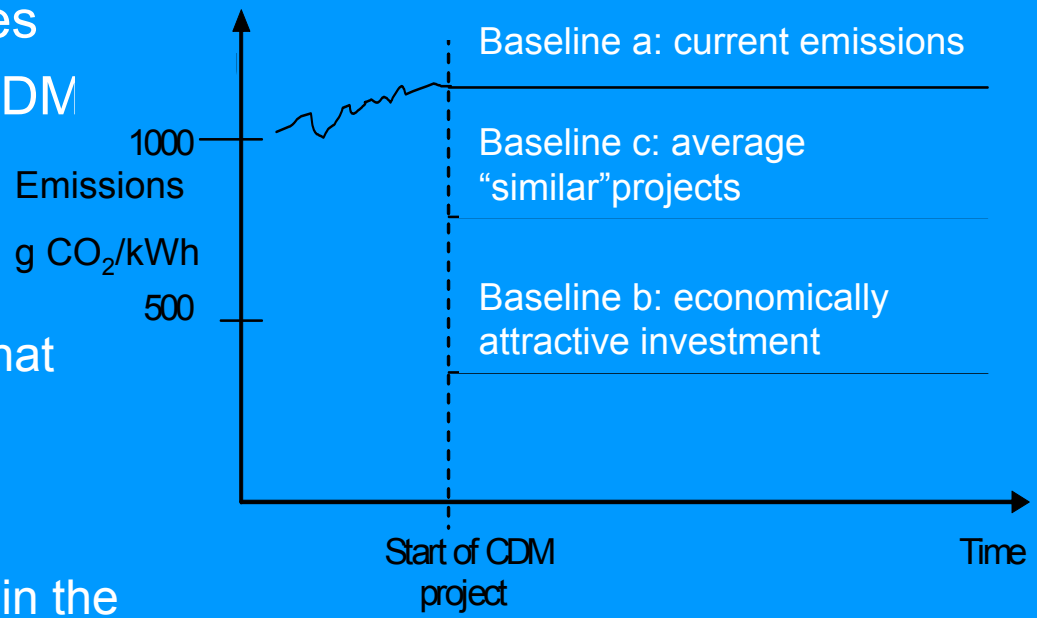
Baseline Approach

- Baseline methodologies can be chosen among 3 approaches (§ 48 Marrakesh Accords CDM M&P):

a) Existing **actual or historical emissions**,

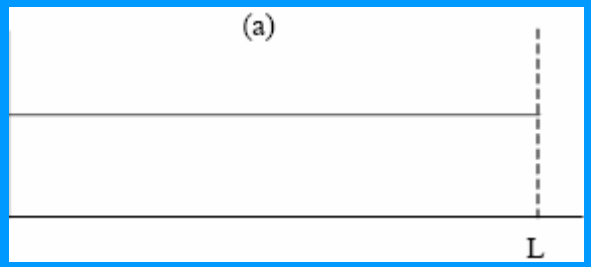
b) Emissions from a technology that represents an **economically attractive** course

c) Average emission of **similar projects** activities undertaken in the previous 5 years, in similar circumstances, and whose performance is among the top 20% of their category.

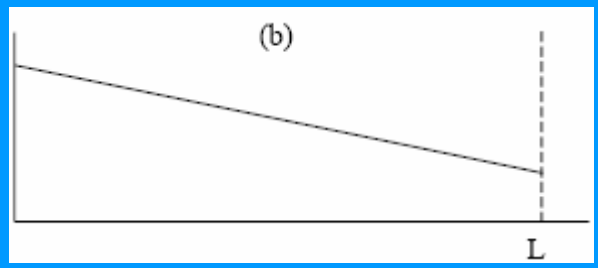


a- old coal fired power station 1200 g CO_2/kWh.
b - gas combined cycle 400 g CO_2/kWh
c- 850 g CO_2/kWh

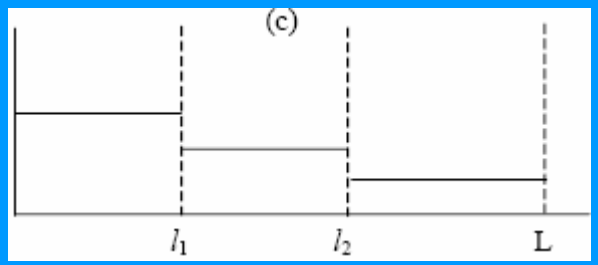
Four Main Types of Baseline Variation Over Time



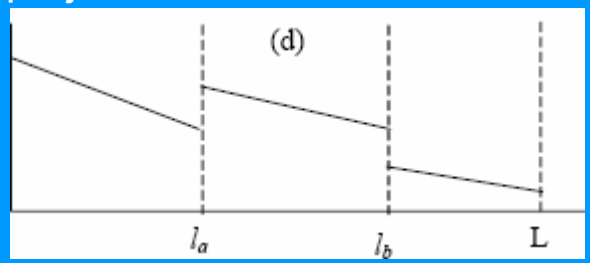
a) *constant, no revision baseline* parameters do not vary over crediting lifetime, L,with values set on the project start date



b) *time-varying, no revision baseline* parameters vary over crediting lifetime according to calculations agreed at project start date



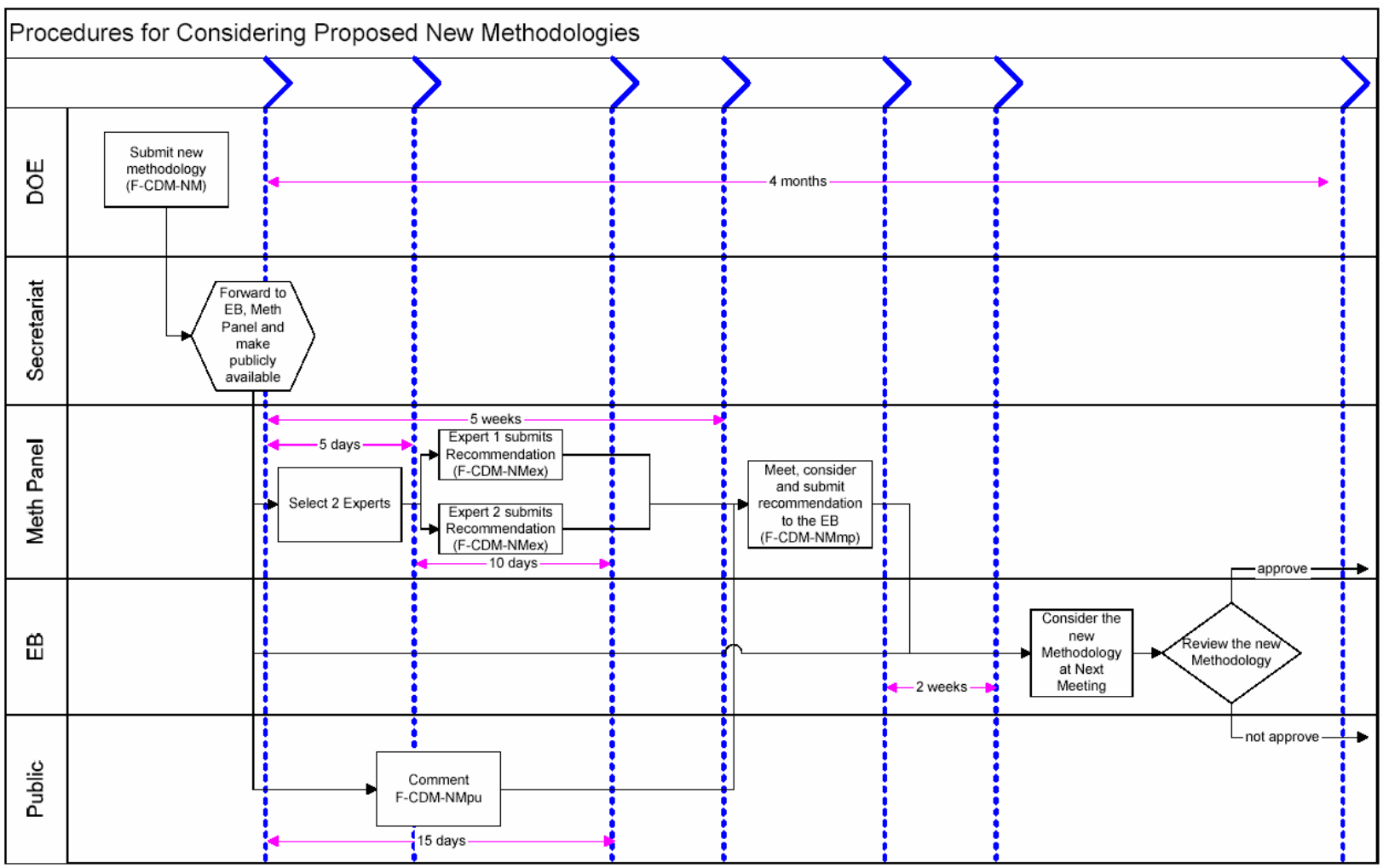
a) *constant, periodic revision baseline* parameters do not vary during periods I_1, (I_2-I_1), $(L-I_2)$, but values are revise at I_1, I_2



b) *time-varying, periodic revision baseline* parameters vary over period I_a, according to calculations agreed at project start date, over period $(L-I_b)$, according to calculations agreed at according to calculations agreed at I_b

4. Procedure for Baseline Approval

Procedure for Approval of New Methodologies



Some of the Approved Baseline Methodologies

	Zero emission renewables:
ACM2	Grid-connected electricity generation for renewable sources (no biomass, no reservoir extension)
AM5	Small grid-connected zero-emission renewable electricity generation
	Biomass:
AM4	Grid-connected biomass power generation that avoids uncontrolled burning of biomass.
AM7	Switch from coal/lignite to seasonal agro-biomass power
AM15	Bagasse-based cogeneration connected to an electricity grid (use additionality tool)
	Waste
ACM1	Landfill gas project activities
AM2	Landfil gas Capture & flaring with public concession contract (ex-post baseline correction)
AM3	Simplified financial analysis for landfill gas capture projects (no CERs from electricity) (ex-ante correction)
AM10	Landfill gas electricity (CERs from electricity)
AM11	Landfill gas recovery with electricity generation (no CERs from electricity)
AM12	Biodigester power from municipal waste (only India)
	Animal waste:
AM6	Biogas power from swine manure
AM13	Biogas power from open anaerobic lagoon waste water treatment systems
AM16	Change of animal waste management systems
	Fossil fuel switch:
AM8	Fuel switch from coal/oil to natural gas
AM14	New cogeneration unit using natural gas at an industrial plant
	Fugitive emission from fuels:
AM9	Recovering associated gas in stead of flaring
	HFCs:
AM1	Incineration of HFC23 waste streams from HCFC22 production

5. Approaches for Power Sector Baselines

Methodologies for Power Sector Baselines (I)

Methodologies

- ACM 0002 “Consolidated baseline methodology for grid-connected electricity generation from renewable sources”
- AM 0005 “Baseline methodology (barrier analysis, baseline scenario development and baseline emission rate, using combined margin) for small grid-connected zero emissions renewable electricity generation”

Applicability

ACM 002

Applies to electricity capacity additions from:

- Run-of-river hydro power plants;
  hydro power projects with existing reservoirs
  where the volume of the reservoir is not increased
- Wind sources; - Solar Sources
- Geothermal sources ; - Wave & tidal sources

AM 0005

- Small (<15 MW) grid-connected zero emissions renewable electricity generation

Not if proposed CDM activity retrofit or modification of existing facility

Methodologies for Power Sector Baselines (II)

Project Boundary

- Regional project electricity system defined by spatial extent of power plants dispatched without significant transmission constraints
- Electricity exports are also generation!
- Special rules for electricity import emission factors; 0 t CO_2/MWh if from other country

In small and medium sized countries, define project electricity system = country

Combined Margin Approach (ACM0002)

- **Calculate a baseline emission factor *EFy*** as the weighted average of the Operating Margin emission factor (*EF_OMy*) and the Build Margin emission factor (*EF_BMy*,):

$$EFy = (wOM * EF\_OMy) + (wBM * EF\_BMy)$$

where the weights *w*OM and *w*BM, by default, are 50% (i.e., *w*OM = *w*BM = 0.5)

Operating Margin Methods (1)

- 4 options for calculating the operating margin (regarding ACM0002) :

  a) Simple OM: Weighted-average emission rate excluding low-operating cost and must-run power plants

  b) Simple Adjusted OM: Including some must-run/low-cost resources (e.g. hydro) where they dominate a grid

  c) Dispatch Data Analysis OM

  d) Average OM: Including low-operating cost and must-run power plants

Simple Operating Margin Method (a)

- **Simple OM** method (a) **can only be used** where low- cost/ must-run resources constitute **less than 50%** of total grid generation in:

  1) average of the five most recent years, or

  2) based on long-term normals for hydroelectricity production

- Simple OM emission factor calculation either:
  - 3-year vintage based on most recent statistics, or
  - Update for respective year on ex-post monitoring

Simple Adjusted Operating Margin Method (b)

- Variation of Simple OM Method, where power sources are separated in:
  - low-cost /must-run power sources (usually renewables and nuclear)
  - other power sources (usually fossil-fuel fired power plants)
- $EF_{OM,simple,adjusted,\ y} = (1- \lambda_y)^* EF_{OM,other\ power\ sources} + \lambda_y^* EF_{OM,low\text{-}cost/must\text{-}run}$

λ_y = Number of hours per year for which low-cost/must-run sources are on the margin / 8760 hours per year

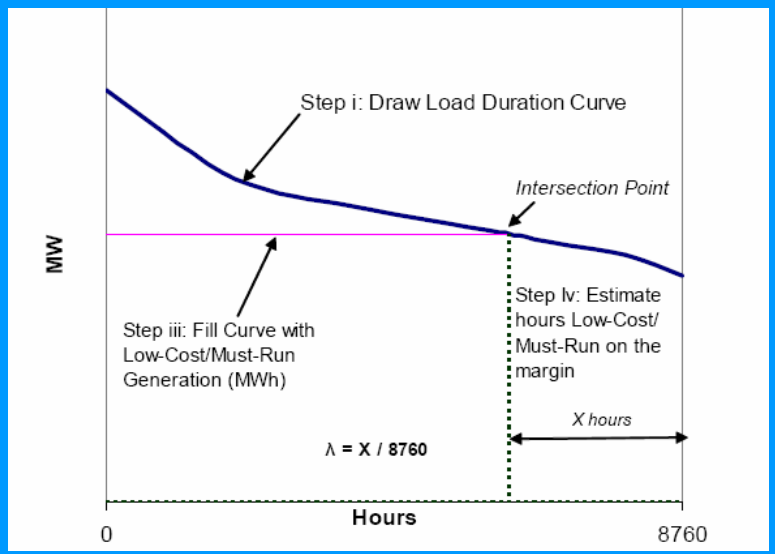
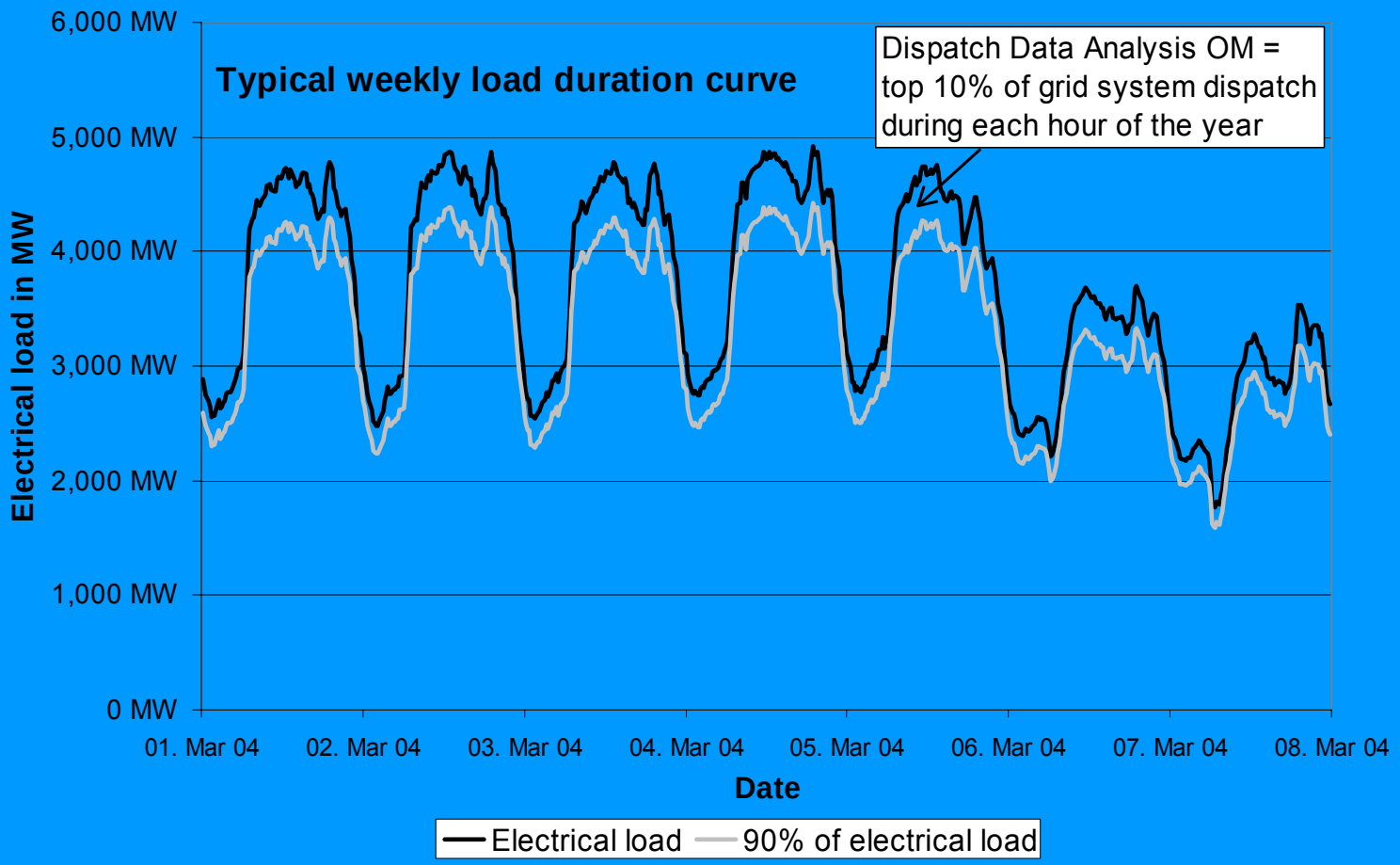


Illustration of lambda (λ) calculation

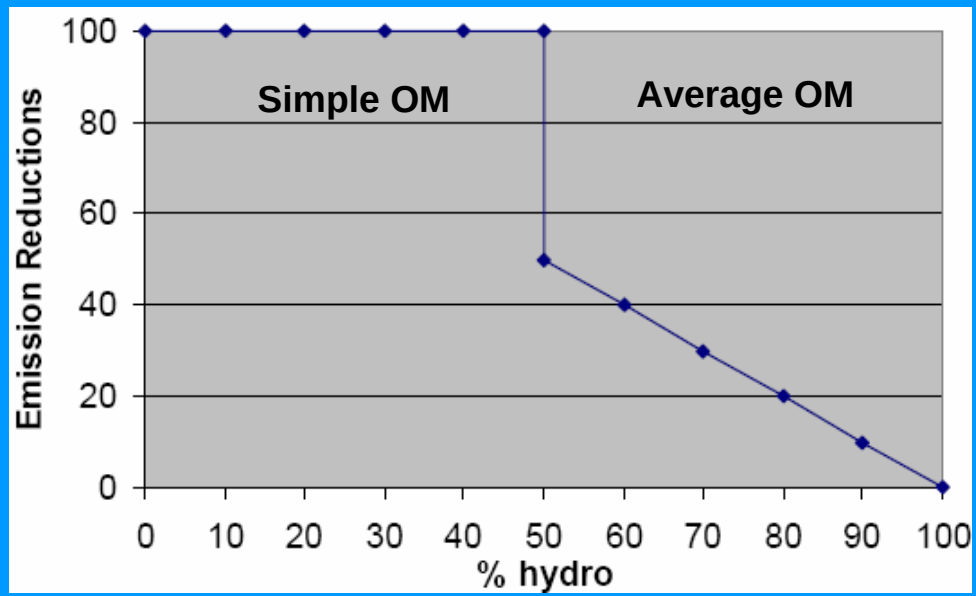
Dispatch Analysis
Operating Margin (c)



Average Operating Margin Method (d)

Average OM method (d) can only be used where low-cost/ must-run resources constitute **more than 50%** of total grid generation and data for simple OM (b) or Dispatch Analysis OM (c) is not available

Behavior of emission reductions under ACM0002



Average OM method yields low baseline emissions and consequently low credits !

Build Margin Method

- 1 option for calculating the build margin (regarding ACM0002):
  … the generation-weighted average emission factor of a sample of power plants *m*, as follows,

  EF_BMy = ∑ FUEL USE * EMISSION COEFF/GENERATION

  where the sample group *m* consists of either
  - the 5 most recent or
  - the most recent 20% of power plants built or under construction,
  - whichever group's average annual generation is greater (in MWh);

6. Impact of Baselines

Financial Impact of CO_2 Revenues

	Investment Cost	CO2 Revenues as % of Investment Cost	
	US$ / kW	@ 400 t/GWh	@ 1000 t/GWh
Hydropower-Small	1300	6.4%	15.9%
Wind Turbines - kW Size	1350	3.3%	8.2%
Wind Turbines - MW Size	900	4.9%	12.4%
Biomass	1250	8.7%	21.6%

Source: World Bank

7. Conclusion

Conclusion

- The Marrakesh Accords reached at COP-7 proposed some broad principles for baseline development.

- When choosing among various approaches, project developers should take into account:
  - the level of complexity,
  - conservatism,
  - availability of data,
  - expected return,
  - transaction costs, and
  - available expertise for choosing the baseline

8. Country Emission Factors

CO_2 Emissions per kWh from Electricity and Heat Generation (all fuels)

Country	CO2 Emissions (grams CO_2 / kWh)														
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Annex I Countries	..	..	..	..	425	414	418	414	429	432	433	429	426	429	429
France	95	118	104	118	93	63	64	71	72	66	92	80	78	62	70
Germany	574	573	571	584	553	550	548	533	541	532	509	495	500	505	518
Italy	543	565	574	544	535	522	518	549	527	517	518	499	507	485	509
Romania	478	501	538	561	410	384	456	441	444	385	351	360	395	412	412
Russia	..	..	..	..	308	291	296	292	342	328	327	327	321	322	327
Ukraine	..	..	..	..	359	362	351	351	323	324	333	327	326	328	321
United Kingdom	685	669	679	663	647	571	542	547	514	477	479	433	448	471	455
United States	608	584	566	556	584	587	583	567	576	600	601	593	583	599	579

Country	CO2 Emissions (grams CO2 / kWh)														
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Non-Annex1															
Armenia	..	..	..	..	400	110	126	214	220	264	258	225	236	243	153
Azerbaijan	..	..	..	..	778	857	482	504	522	533	543	633	644	631	570
Georgia	..	..	..	..	367	319	273	488	166	153	162	154	193	133	52

Source: http://www.ghgprotocol.org/standard/tools.htm, based on International Energy Agency, 2004

CO_2 Emissions per kWh from Electricity and Heat Generation Using Gas

Country	CO2 Emissions (grams CO_2 / kWh)														
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Annex I	0	0	0	0	337	320	334	339	362	365	365	365	356	354	357
France	345	325	337	342	332	339	332	335	349	335	340	361	515	297	346
Germany	358	366	372	376	355	333	330	314	360	371	342	360	345	314	327
Italy	477	474	475	479	476	475	457	466	459	442	446	439	431	402	435
Romania	856	848	930	1007	279	271	332	322	317	284	288	285	296	292	307
Russia	..	..	..	..	261	248	259	259	290	286	288	286	293	298	301
Ukraine	..	..	..	..	345	343	335	347	343	350	363	350	355	363	355
United Kingdom	532	531	521	488	488	479	426	427	434	410	411	386	382	382	376
United States	531	543	550	537	532	506	510	509	546	561	540	541	462	455	439

Country	CO2 Emissions (grams CO2 / kWh)														
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Non-Annex1															
Armenia	..	..	..	..	224	226	250	328	467	471	473	457	457	458	454
Azerbaijan	..	..	..	..	..	..	341	341	341	336	305	590	546	564	507
Georgia	..	..	..	..	446	445	254	935	971	935	923	924	887	616	644

Source: http://www.ghgprotocol.org/standard/tools.htm, based on International Energy Agency, 2004

CO_2 Emissions per kWh from Electricity and Heat Generation Using Coal

Country	CO2 Emissions (grams CO_2 / kWh)														
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Annex I	..	..	..	..	821	807	806	814	847	843	846	849	827	849	850
France	1143	1099	1061	1018	976	1032	1108	1132	1020	1079	1044	1054	1051	1160	1123
Germany	873	874	856	884	868	870	875	872	878	871	826	826	831	873	908
Italy	936	958	951	968	998	991	1019	1013	1003	1029	1046	1053	1058	994	1004
Ukraine	..	..	..	..	458	515	514	509	481	485	520	515	518	523	509
United Kingdom	919	921	921	897	916	875	866	918	891	932	950	920	863	902	896
United States	905	895	898	885	920	932	929	922	927	923	928	924	917	960	941

Country	CO2 Emissions (grams CO2 / kWh)														
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Non-Annex 1	..	..	..	..	1024	1008	1000	1016	1016	1042	1051	1011	985	979	955
Armenia	..	..	..	..	0	0	0	0	0	0	0	0	0	0	0
Azerbaijan	..	..	..	..	0	0	0	0	0	0	0	0	0	0	0
Georgia	..	..	..	..	607	607	0	967	0	0	0	0	0	0	0

Source: http://www.ghgprotocol.org/standard/tools.htm, based on International Energy Agency, 2004

CO_2 Emissions per kWh from Electricity and Heat Generation Using Oil

Country	CO2 Emissions (grams CO_2 / kWh)														
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Annex I	0	0	0	0	528	494	506	485	499	548	551	552	574	561	558
France	692	650	606	642	592	502	464	509	522	487	568	541	526	582	605
Germany	560	542	500	405	401	380	475	367	315	316	322	336	440	509	517
Italy	688	677	675	674	667	664	658	666	664	661	658	668	706	708	642
Ukraine	..	..	..	..	536	500	461	480	417	428	418	437	437	473	551
United Kingdom	667	704	663	724	766	820	899	673	670	636	545	239	458	539	446
United States	723	707	671	639	595	559	538	491	494	739	784	782	810	708	721

Country	CO2 Emissions (grams CO2 / kWh)														
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Non-Annex I	0	0	0	0	747	755	750	740	742	750	763	757	739	732	732
Armenia	..	..	..	..	936	421	374	307	575	479	0	0	0	0	0
Azerbaijan	..	..	..	..	524	673	600	603	626	675	728	701	736	896	914
Georgia	..	..	..	..	633	639	1150	1356	1061	1060	1061	1060	1058	3050	2648

Source: http://www.ghgprotocol.org/standard/tools.htm, based on International Energy Agency, 2004

9. Workshop:
Calculation of Country- Specific Power Sector Baseline

THANK YOU