Tool to Calculate the Emission Factor for Energy Embedded in Water Delivered to End-Users

DRAFT

Situation Analysis

Water and wastewater systems are a significant source of energy demand and greenhouse gas emissions, not to mention the largest energy expenditure for most municipal governments, however, awareness of the energy dimension of water remains low. Water savings and energy savings are linked and can be addressed forcefully together. In the UAE, for example, savings of energy embedded in water are nearly twice as large as savings in grid electricity used by clothes washing machines, due to energy-intensive desalination.

Analogous to energy efficiency projects (e.g., programs that replace incandescent lamps with CFLs that use 75% less energy to deliver the same light output), which are credited with avoiding greenhouse gas emissions that would have resulted from supplying electricity, project activities that improve the efficiency of water use avoid greenhouse gas emissions that would have been needed to deliver water for the end-use.

Globally, most water is used for agricultural purposes, but industrial and residential use are also significant. We therefore developed a "Tool to Calculate the Emission Factor for Energy Embedded in Water Delivered to End-Users", which can be used by water efficiency projects in any sector.

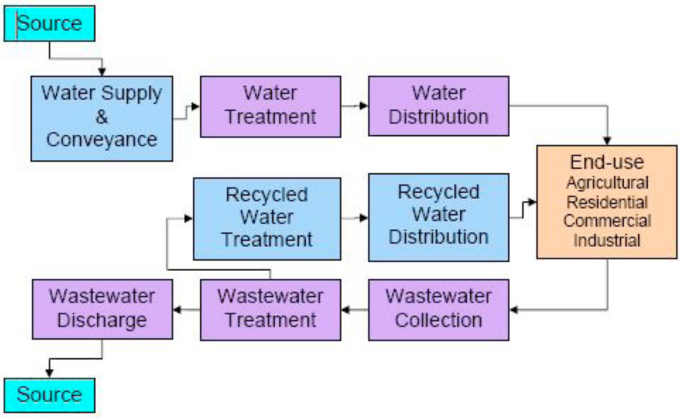
Purpose

The ultimate objective of the work is a CDM methodology tool that credits greenhouse gas emission reductions due to water efficiency improvements, which reduce water demand and the energy that would have been consumed to deliver it, analogous to the "Tool to Calculate the Emission Factor for an Electricity System". The immediate objective of KfW, as reflected in this Final Report, was to develop a stand-alone, open-source "Tool to Calculate the Emission Factor for Energy Embedded in Water Delivered to End-Users", as a basis for discussion and further development.

Results

Policy goals, the tool, its defaults, and all other parts are compiled below. Key features of the proposed tool are:

- Universal applicability: This tool can be applied in all public water grids across all CDM host countries.
- Comprehensive scope, modular structure: The tool presents a comprehensive conceptual framework to derive an aggregate CO_2 emission factor for energy embedded in water delivered to end-users, by calculating the energy intensities of the components of the water supply system. A generic water supply system consists of the following components:



This initial tool proposal only covers components upstream of the end-user, namely water source extraction and conveyance to treatment facilities, desalination, water treatment, and water distribution to end-users. However, the tool may be subsequently expanded to include the wastewater handling system downstream of the end-user, including wastewater collection, treatment and discharge.

- Methodological options: The tool contains at present two approaches, Option 1 offers conservative default values and Option 2 is a simple input-output approach. Neither approach requires detailed operational data for facilities included in the water supply system, as this would be beyond the reach of most water efficiency project developers. It is possible to include an engineering approach as a third option. Option 1 offers both highly conservative, system-level defaults, as well as process level defaults that yield more accurate (less conservative) estimates, but require comprehensive data on the technologies deployed, water volumes handled and characteristics of the water conveyance and distribution system.
- Tool users: Public grid operators and Designated National Authorities (DNAs) might be particularly well-placed to apply the tool and regularly publish emission factors for energy embedded in water delivered to end-users, which can be applied by water efficiency project developers.
- Integration of water loss approaches: Technical and theft water losses vary between 7 and 70% of water volume. The tool allows to reflect water losses and can therefore be effective in highlighting inefficiencies in public water grids – which represent opportunities for municipalities to cut wastage and costs themselves, including leveraging carbon finance for loss reducing investments.
- Conservativeness: The proposed default values have been proposed based on an extensive literature review. The system-level defaults under Option 1 are the most conservative, followed by the process-level defaults, because the selected default values correspond to the energy intensities of the most efficient plants operating globally. Option 2 is less conservative because all individual electricity users including those with low efficiencies are accounted for.
- Excel calculation spreadsheets: Templates have been provided to support the data handling. None of them contain technology assumptions and they reflect only the equations in the tool. When more than one grid is analyzed, the spreadsheets ease data gathering since applied to regions, the tool quickly implies hundreds of units.

Outlook and Possible Next Steps

The tool would benefit from in-depth peer review and road-testing. The Methodology Panel can decide to assess the tool in its present form (as below), or more parts or an engineering option, especially for distribution and desalination, are added before submitting this tool to the Panel.

Host countries with energy intensive water supply systems and water scarce countries would be natural starting points. The first step is to determine whether sufficient data are publicly available to apply either the input-output approach or to make use of the process-level default values. If not, collecting this data systematically would be a priority and would hopefully encourage public entities to address inefficiencies in the public water supply system at their source, as well as to promote water efficiency efforts, both of which can be highly cost-effective. Depending on the grid operators' accounting, public and private, different combinations of the options can prove to be practicable.

A number of approved methodologies with water efficiency components could be revised to reference the tool. Parts of this tool can be used in other methodologies covering certain parts of water grids or certain water uses. To include wastewater treatment, it is necessary to reflect the methodologies for methane emission in wastewater systems, notably ACM014 and AMS-III.H.

Even without wastewater or other parts, an approved tool will enable a wide variety of water saving technologies to be linked to carbon finance. The tool uptake will certainly indicate where its applicability can be expanded.

Procedure

Neither the "CDM Modalities and Procedures", nor the guidance issued by the CDM authorities, contain a procedure for submitting a new tool for approval by the CDM Executive Board and none have been created. We have prepared this draft tool by completing Sections B and C of the CDM-NM form, with certain sub-headings excluded, analogous to the structure of the "Tool to Calculate the Emission Factor for an Electricity System".

Table of Contents

Possible policy concerns for designing the Water Tool

1. Demonstrate effective Methodology Panel input and bottom-up innovation
2. Enable the Methodology Panel to get started with a broad Water Tool that facilitates many different water savings projects - Tool allows for any specific water saving technology (comprehensiveness can limit geographic coverage)
3. Anticipate the most difficult Tool parts where Methodology Panel deliberations could get entangled (such as Brazilian low-cost must-run issue in the electricity grid tool) - propose suitable compromises esp. for distribution grids, desalination and wastewater on accuracy vs. usability
4. Align other CDM innovators behind a particular Water Tool approach - information for other CDM innovators after the first submission and the initial Methodology Panel reaction
5. Identify those Tool parts that allow to enlarge the geographical coverage, in other words, Tool parts that increase usability in diverse institutional context (private or public water utilities, hydrological particularities and so on)
6. Identify those Tool parts where the Methodology Panel appreciates getting help with - probable candidates distribution and desalination
7. Identify those Tool parts where subject matter competence will create the biggest impact on Methodology Panel thinking
8. Reduce transaction costs for water CDM projects, i.e. ease of project participants in applying the water tool (similar to 5. but stronger)
9. Enable DNAs to develop water emission factors for their countries, similar to the practice in applying the electricity grid tool (similar to 2. but stronger)
10. Reflect different water supply technologies with sufficient precision so that modernisations are supported, for example wastewater treatment with more biogas and less land-filling, or more efficient desalination technologies
11. Support linkages between the Water Tool and other methodologies, for example the electricity grid tool, the wastewater methane tool and other water related methodologies
12. Enlarge variety of CO_2 emission reductions in carbon portfolios - e.g. agriculture
13. Support innovation for appliance CDM projects for example with water saving washing machines and dishwashers

In the following table some important policy aspects relevant for each option and system component are suggested (with the numbers in above list). These suggestions are illustrative and many others are possible reflecting various CDM objectives. These suggestions are not exhaustive nor authoritative. They are quite common, neutral to current water sector concerns and first of all formulated for the future expansion of the CDM as such.

Water System/ Subsystem	Energy Use Determinants	Option 1 Default Values	Option 2 Input-Output Approach	Option 3 Engineering Approach
		Amount of embedded CO2e per volume Published by water companies Reported by other sources	Total energy use and total water delivered to end-users Published by utilities Reported by other sources	Design data or operational data for mayor physical process Suppliers or operators
Source extraction & conveyance	Source type & location Geography Pump system efficiency Leakage	Defaults per meter Defaults cannot be derived without local data **5** applicable in countries with uncooperative utilities when only volumes per source are known (and all small countries)	**2** some support for comparison over variety of sources **9** offers impact for data collection by government, impact on 8 dependent on DNA	EPANet-like grid model calibrated to UK regulat **5** the other options are more likely than for distribution, so fewer added countries **8** existing data, easy to identify and accurate
Desalination	Technology Co-gen operational management decisions Water salinity	Defaults per m^3 Design system parameters **8** no data required, limited to RO (~all non-Opec, only Algeria all RO, islands), also limited because desalter scheduling ignored	build margin for several plants used **3** shortcut for fuel separation between electricity and water **4** only RO technology suppliers, thermal more conservative	operating margin at load **3** accuracy but requires utility cooperation **6** difficult for MP to find suitable expertise for thermal technologies
Water treatment	Technology (water qual.) Scale	Defaults per m^3 **7** filtration types need different defaults, sludge treatment technologies, disinfection and flocculation contain most parameters	**9** offers impact for data collection by government	little impact as all stages are easy to calculate if the required data is collected
Distribution	Geography Pump system efficiency Leakage Grid characteristics Grid control system	Defaults per meter Defaults cannot be derived without local data **5** enables small grid approximation Defaults per m^3 **8** no data required for medium sized grids (10-100k inhabitants)	**5** probably some in countries with cooperative and unsophisticated utilities **9** offers impact for data collection by government, impact on 8 dependent on DNA	EPANet-like calibrated to UK regulation **3** competing software **4** USEPA or other modelers **5** adds cases when other options cannot be used (large grids), reduces only when no modeled grid and other options impossible **6** difficult for MP to find suitable expertise **8** existing data, easy to identify and accurate
Wastewater collection, treatment & discharge	Technology Scale Sludge re-use	Defaults per m^3 and per cap **5** adds those countries with uncooperative utilities	**9** offers impact for data collection by government **10** sufficient to reflect efficiency differences esp. of sludge processes	**10, 11** integrate methane avoidance and power generation

Draft Tool

UNFCCC	**CDM: Proposed New Methodology** **Meth Panel recommendation to the Executive Board** **To be completed by UNFCCC Secretariat**
Date of Meth Panel meeting:	
Related F-CDM-NM document ID number (electronically available to EB members)	F-CDM-NM0 : “ ”
Related F-CDM-NMex document ID number(s) (electronically available to EB members)	F-CDM-NMex0 :
Related F-CDM-NMpu document ID number(s) (electronically available to EB members)	F-CDM-NMpu0 :

Signature of Meth Panel Chair ……………………………………………..
Date:

Signature of Meth Panel Vice-Chair ……………………………………………..
Date:

Information to be completed by the secretariat

F-CDM-NMmp doc id number	NM
Date when the form was received at UNFCCC secretariat	
Date of transmission to the EB	
Date of posting in the UNFCCC CDM web site	

NM0xxx Version ## (to be completed by UNFCCC)

CLEAN DEVELOPMENT MECHANISM
PROPOSED NEW BASELINE AND MONITORING METHODOLOGIES (CDM-NM)
(Version 03.1)

CONTENTS

Instructions for using this form

In using this form, please follow the guidance established in the following documents:

- Guidelines for completing the project design document (CDM-PDD) and proposed new baseline and monitoring methodologies (CDM-NM);
- Technical guidelines for the development of new baseline and monitoring methodologies (contained in part III of the above);
- Relevant methodological guidance by the Executive Board.

This guidance can be found at <https://cdm.unfccc.int/Reference/Guidclarif/index.html>

Formatting Instructions:

- The form provides the formatted headings which should be used throughout the document;
- Please note that each paragraph in section C and D should have a paragraph number, as demonstrated through example. When adding further paragraphs, please ensure it is numbered;
- Please use word equation editor to write equations;
- Please format figures, tables and footnotes to update automatically;
- Please note the footnotes have a separate format (Times New Roman - size 10).[1]

Please complete sections B to E. In section C, the text shaded in grey shall not be changed, whereas other text is used as an example and may be changed or deleted.

[1] Format for footnotes.

Section A. Recommendation by the Methodological Panel (to be completed by the Meth Panel)

Intentionally left blank

Recommendation (preliminary or final / approval or rejection / consolidation)

>>

2. Major changes required

>>

3. Minor changes required

>>

Section B. Summary and applicability of the baseline and monitoring methodology

1. Methodology title (for baseline and monitoring), submission date and version number

>> Tool to Calculate the Emission Factor for Energy Embedded in Water Delivered to End-Users
8 March 2012
Version 1.0

2. If this methodology is based on a previous submission or an approved methodology, please state the reference numbers (NMXXXX/AMXXXX/ACMXXXX) here. Explain briefly the main differences and their rationale.

>>

3. Summary description of the methodology, including major baseline and monitoring methodological steps

>> This methodological tool provides procedures to derive an aggregate CO_2 emission factor for energy embedded in water delivered to end-users, by calculating the energy intensities of the components of the water supply system. This initial proposal only covers components upstream of the end-user[2], as defined in Annex 1, namely water source extraction and conveyance to treatment facilities, desalination, water treatment, and water distribution to end-users.

The CO_2 emission factor for energy embedded in water supplied to end-users determined using this tool can be used by any new or existing end-use efficiency methodology that involves water-using technologies (e.g., irrigation systems, washing machines or industrial processes).

[2] The tool may be subsequently expanded to include the wastewater handling system downstream of the end-user, including wastewater collection, treatment and discharge.

Section C. Proposed new baseline and monitoring methodology

Draft baseline and monitoring methodology AMXXXX

"Tool to Calculate the Emission Factor for Energy Embedded in Water"

I. SOURCE, DEFINITIONS AND APPLICABILITY

Sources

This methodology also refers to the latest approved versions of the following tools (please delete those not applicable):

- Tool to Calculate the Emission Factor for an Electricity System

For more information regarding the proposed new methodologies and the tools as well as their consideration by the Executive Board please refer to http://cdm.unfccc.int/goto/MPappmeth.

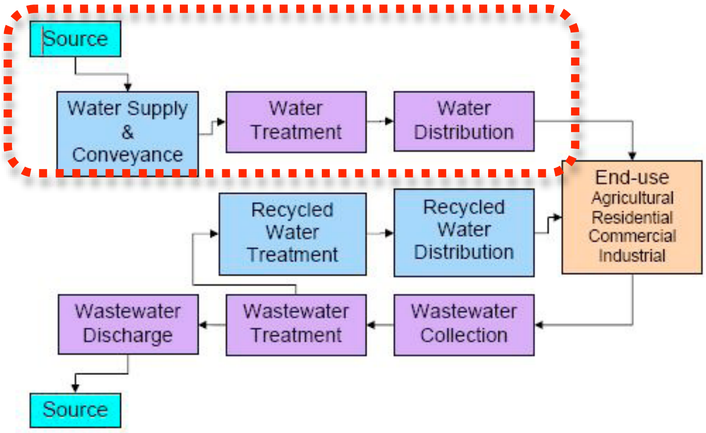
Definitions: Please provide definitions of key terms that are used in this proposed new methodology

1. For the purpose of this methodology, a compilation of definitions is provided as Annex 1 of Section C.

Applicability conditions

2. This tool may be applied to estimate the aggregate CO_2 emission factor for energy embedded in water delivered to end-users and/or the amount of electrical and fossil thermal energy embedded in water, when calculating baseline emissions for a project activity that results in savings of water that would have been provided by a water system (e.g. demand-side energy efficiency projects involving water-using technologies).

3. This methodological tool determines the CO_2 emission factor for energy embedded in water delivered to end-users, by calculating the energy intensities of the components of public water supply system upstream of the end-user (see figure, components outlined in red). Upstream components, as defined in Annex 1, include water source extraction and conveyance to treatment facilities, desalination, water treatment, and water distribution to end-users. The respective energy intensities are multiplied by the relevant grid emission factors or fossil fuel emission factors. The "Tool to Calculate the Emission Factor for an Electricity System" is referenced.



4. The methodology is applicable under the following conditions:

   (a) The upstream components of the public water system that supplies the project activity are located within CDM-eligible host countries.

   (b) The project activity complies with additional applicability conditions that pertain to methodological options, as outlined in the respective sections below.

5. In addition, the applicability conditions included in the tools referred to above apply.

II. METHODOLOGY PROCEDURE

6. The tool presents two of three possible methodological options; project proponents may apply either option, alone or in combination[3]:

Option 1 – Default Values

7. When using default values (as provided by Option 1), additional applicability conditions apply:

   (a) The source(s) of water in the relevant water grid are known and, if desalination is involved, the desalination technology used and the share of water sourced by desalination are known.

   (b) If the water grid supplying the project activity can physically exchange water with another grid, that that grid shall also be included.

8. Under Option 1, PPs may select an appropriate level of aggregation, with the system-level defaults generally being the most conservative.

9. At the most aggregated (water system) level, the emission factor for energy embedded in water delivered to end-users ($EF_{CO2,water,y}$) is determined by multiplying the grid electricity emission factor times the appropriate (Level 1) default energy intensity values:

$$EF_{CO2,water,y} = EE_{water} * EF_{CO2,elec,y} \quad \textbf{(1)}$$

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[3] To cover the variety of data access situations, a third option with engineering calculations can be added. This engineering option reflects the main physical processes. For water conveyance and distribution grids, realistic monitoring uses data from grid models used for planning and maintenance such as EPANet (3.0). Distribution grids can not be calculated manually and when sufficiently modelled distribution data in larger towns are available, smaller towns can be conservatively excluded.

Where:

$EF_{CO2,water,y}$	Aggregate CO_2 emission factor for embedded energy in water supplied to end-users in year *y* (tCO_2/1000 m^3)
EE_{water}	Embedded electricity in water supplied in year *y*, using the appropriate Level 1 default value from Table 1 (MWh/1000 m^3)
$EF_{CO2,elec,y}$	Emission factor for grid electricity in year y (tCO_2/MWh)

Table 1. Energy Intensity Default Values by Level and Water System Component

Parameter	Defaut Value (MWh/1000 m^3)	Applicability
Level 1 – System Level Defaults		
EE_{water}	0.3	Systems that do not include desalination
EE_{water}	14	Systems that supply over 90% of water through desalination using evaporation technology
EE_{water}	3	Systems that supply water in part or totality from reverse osmosis
Level 2 – Processes Level Defaults		
EE_{WTP1}	3	Water pre-treatment and desalination by reverse osmosis
EE_{WTP2}	0	Removal of Iron (Fe) and Manganese (Mn)
EE_{WTP3}	0	Softening
EE_{WTP4}	0	Flocculation and coagulation
EE_{WTP5}	0.04	Dissolved air flotation
EE_{WTP6}	0.0002	Adsorption
EE_{WTP7}	0.05	Aeration
EE_{WTP8}	0.0003	Chlorine dioxide
EE_{WTP9}	0.0001	Chlorination
EE_{WTP10}	0.0002	slow sand filtration, activated carbon, rapid gravity filtration
EE_{WTP11}	0.07	Ozonation
EE_{WTP12}	0.08	UV disinfection
EE_{WTP13}	0.04	Microfiltration
EE_{WTP14}	0.03	Ultrafiltration subdefaults see Table 3
EE_{WTP15}	0.3	Nanofiltration
EE_{WTP16}	0.3	Reverse osmosis as one step within a treatment plant
EE_{wtp17}	0.001	Sludge treatment subdefaults see Table 4

10. When using Level 2 defaults, additional applicability conditions apply:

(a) All water treatment plants operating with these sources are recorded and the total annual water volume per treatment plant has been established.

11. For Level 2, $EF_{CO2,water,y}$ is determined as in Equation 1, but the EE_{water} term is calculated as follows (rather than relying on the Level 1 defaults):

$$EE_{water} = EE_{convey+distrib} + EE_{treat} + EE_{desalt} \quad (2)$$

Where:

EE_{convey} Embedded electricity from water conveyance in year *y* (MWh/1000 m^3 water), estimated according to Equation 3.

EE_{treat} Embedded electricity due to water pre-treatment and treatment in year *y* (MWh/1000 m^3 water), according to Equation 4

EE_{desalt} Embedded electricity due to desalination with reverse osmosis in year y (MWh/1000 m^3 water), using the appropriate value from Table 5. When WTP1 (pre-treatment with reverse osmosis) is included in estimating EE_{treat}, this term shall be set to zero.

12. The amount of energy required to move water depends on local geography, so the term $EE_{convey+distrib}$ is estimated as follows:

$$EE_{convey+distrib} = (Spd \times Lm \div 9{,}807 + Vm) \times 9.81 \times 3.6 \div \eta_{max} \qquad \textbf{(3)}$$

Where:

$EE_{convey+distrib}$	Electricity required for water conveyance and distribution	(MWh/1000m3)
Spd	Specific pressure drop default for water mains in conveyance and distribution (Pa/km). Default values taken from Table 2 are based on either mains diameter or flow rate; for intermediate values, select the next (lower) pressure drop.	
Lm	Average horizontal main length between source and water treatment, and/or between sources and distribution reservoirs	(km)
Vm	Vertical (geodetic) distance between source and water treatment, and/or between sources and distribution reservoirs	(m)
η_{max}	Maximum pump efficiency default from Table 2	(-)

The geographic centre of the water distribution grid shall be used for horizontal distances. Values for Spd, Lm and Vm can be used for sections or for the whole conveyance. All pumping stations for the sources are identified. The annual water volume per station has been established when sections are added (annual average flows applied in Table 2). Vertical conveyance pumping energy shall be established for each water source. The average geodetic distance (Vm) shall be calculated based on annual total water volumes from each source for each water treatment plant. When the elevation of the treatment plant is not the highest in the conveyance system, the highest point shall be used instead. All mains between treatment plants and reservoirs for gravitation distribution shall be recorded and defaults for pump efficiency shall be applied.

Table 2. Default Values to Estimate Energy Intensity of Conveyance and Distribution

Parameter	Default Value	Applicability[4]	
Spd	Specific Pressure Drop (Pa/km)	Mains diameter (cm)	Volume flow (m^3/s)
	98,000	8	0.0040
	73,550	10	0.0063
	56,880	12.5	0.0098
	50,000	15	0.0150
	39,000	20	0.0283
	36,300	25	0.0466
	27,500	30	0.0707
	26,480	35	0.101
	24,500	40	0.138
	22,550	50	0.236
	21,570	60	0.368
	20,594	70	0.539
	20,594	80	0.779
	20,594	90	1.150
	20,594	100	1.375

[4] Mains diameter and flow volume are for optimal mains designs. Can be used alternatively to select the default. Use the lower default when actual parameter is between two rows. Mains below 8 cm diameter are for distribution to individual pressure zones and are not calculated manually.

	20,594	>100	
Maximum Pump Efficiency		Flow volume (m^3/s)	
η_{max}	0.94	> 5	
	0.90	> 0.5	
	0.88	> 0.2	
	0.86	> 0.1	
	0.83	> 0.05	
	0.78	> 0.02	

13. The term EE_{treat} is estimated as follows:

Step 1. Determine the number and type of treatment stages (chlorination and UV disinfection can be used repeatedly in water treatment and shall be added accordingly).

Step 2. Select the corresponding (Level 2) energy intensity default values from Table 1 and perform the following calculation:

$$EE_{treat} = \Sigma_1^m (\Sigma_1^n EE_{WTP_{x,j}} \times Q_{treat,j} \div Q_{grid}) \quad \textbf{(4)}$$

Where:

n	Number of treatment stages in plant *j*	(-)
m	Number of treatment plants supplying the grid	(-)
$EE_{WTPx,j}$	Specific electricity consumption for water treatment process *x* (MWh/1000 m3), using the appropriate Level 2 default values from Table 1, for the treatment plant *j*	
$Q_{treat,j}$	Quantity of water treated in facility *j* in year *y* (1000 m^3)	
Q_{grid}	Quantity of water treated for the entire grid in year *y* (1000 m^3)	

Table 3: Ultrafiltration

	Raw Water Properties			
	<1 NTU, <1 DOC	<1 NTU, 1< DOC <5	<1 NTU <5, <1 DOC	<1 NTU <5, <1 DOC <5
Ultrafiltration (kWh/m^3)	0.1	0.15	0.2	0.3

Table 4: Sludge treatment

	Sludge drying			
Type	kWh/m^3 sludge	Max. kWh/m^3 sludge[5]	kWh/m^3 thicked sludge	Max. kWh/m^3 thicked sludge
chamber filter press	1.0	1.5		
screen filter press	1.3	1.8		
plate pressing	1.0	1.5		
vacuum filter			6.0	12.0
centrifuges	1.2	2.0	3.0	4.0
	Sludge dewatering			

[5] All data on max. specific energy consumption listed only indicate levels of conservativeness of the defaults (to the left) and allow comparison to reported data. The max. specific energy consumption data shall not be used in the EE calculations of EEtreat.

Type	kWh/m^3 water extracted	Max. kWh/m^3 water extracted
sedimentation	0.014	0.02
mechanical	2.8	5.6
thermal	1200	1400

Sand filter backwash water treatment

Type	kWh/m^3	Max. kWh/m^3
Microfiltration		
Ultrafiltration	0.2	1.0
Nanofiltration		

14. The term EE_{desalt} is chosen in the following table reflecting the water pre-treatment and energy recovery technology used in each desalination plant. This default value shall be corrected for water salinity conditions and plant size according to Tables 6 and 7.

$$EE_{desalt} = EE_{desalt,tec} + B + C \quad \textbf{(5)}$$

Where:

$EE_{desalt,tex}$	Specific electricity consumption for reverse osmosis, Table 5, for the plant *j*	(MWh/1000 m3)
B	Correction for salinity of seawater desalted in plant *j*, Table 6	(MWh/1000 m3)
C	Correction for plant size in plant *j*, Table 7	(MWh/1000 m3)

Table 5: Energy Intensity Default Values for Desalination with Reverse Osmosis

	Energy Recovery Technology		
	Work (pressure) exchanger	Turbocharger	Pelton turbine
Water Pre-treatment Technology	MWh/1000m^3	MWh/1000m^3	MWh/1000m^3
Floc gravity filtration + static mixer	3.84	4.32	4.59
Floc gravity filtration + floc basins	4.18	4.30	4.57
Sedimentation + filtration	4.22	4.70	4.97
Flotation + filtration	4.22	4.70	4.97
Membrane filtration (MF, UF or NF)	4.06	4.54	4.81
Flotation + membrane filtration	4.37	4.86	5.13

Table 6: Correction for seawater salinity

Specific electricity consumption changes with seawater salinity

Total Dissolved Solids (ppm, mg/l)	B (MWh/1000m^3)
34,000 - 36,000	-0.44
36,000 - 38,000	-0.22
38,000 - 40,000	0.00
40,000 - 42,000	0.22
42,000 - 44,000	0.44
44,000 - 46,000	0.66
46,000 - 48,000	0.88
48,000 - 50,000	

Table 7: Correction for plant size

Specific electricity consumption for small units sizes

Design desalted water capacity (m^3/d)	C ($MWh/1000m^3$)
< 10,000	-0.2
< 8,000	-0.4
< 6,000	-0.6
< 4,000	-0.8
< 2,000	-1.0
< 500	not credited

15. The following table summarizes how these defaults are to be selected and how they can be weighted.

Table 8: Applying the process level default types (Level 2)

Grid component	Default values	Applications
Conveyance and Distribution	Pumping energy required per horizontal distance between source and water treatment and between treatment and distribution reservoirs *Spd* (Pa/km)	Choose pumping pressure value for the duct diameter or for the flow of each water main. Values represent optimal flow velocities. Applicable for all duct materials. Weigh for parallel mains with respective water volumes. Use hydraulic diameter for noncircular tubes and channels.
	Maximum pump efficiency (-)	Choose maximum pump efficiency for the average water flow pumped through the main (irrespective of type and number of pumps in operation).
Water treatment	Specific electricity consumption for each treatment step EE_{WTP} (MWh/1000m3)	Choose value for each step in operation from Table 1 and add values for all steps (when repeated such as two Ozonations, add for each one, only slow sand filtration and activated carbon are not to be added). When using alternative defaults provided in Tables 4 for sludge, calculate both when possible and use lower one.
Desalination	Specific electricity consumption only for reverse osmosis (MWh/1000m3)	Choose for each desalination plant, among water pre-treatment and energy recovery technology used, weigh for respective water volumes when different technologies are used in parallel and correct for water salinity and design plant capacity (Tables 6 and 7).

Option 2 – Input-Output Approach

16. When using an input-output approach (as provided by Option 2), additional applicability conditions apply:

(a) The annual electricity consumption of the water system as a whole, or for segments or individual facilities has been established.

(b) In cases where water is supplied by desalination, Option 2 is not applicable when only a single thermal desalination unit operates or no electricity-only powerplant operates.

17. The emission factor for energy embedded in water delivered to the end user is calculated by summing up the electricity and fuel use for discrete components of the water supply grid, times the relevant emissions factors:

$$EF_{CO2,water,y} = \left[EF_{CO2,ELEC,y} \times \left(EE_{WS,y} + EE_{DS,y} + EE_{WW,y}\right)\right] + EF_{DS,y} \quad \textbf{(6)}$$

Where:

$EF_{CO2,water,y}$	Aggregate CO_2 emission factor for embedded energy in water supplied to end-users in year *y* ($tCO_2/1000m^3$)
$EE_{WS,y}$	Embedded electricity in water supplied (including conveyance, treatment and distribution but excluding desalination) in year *y* ($MWh/1000m^3$)
$EE_{DS,y}$	Embedded electricity in water supplied by desalination using reverse osmosis under Method 1, if applicable, in year y; otherwise set to zero. When this parameter is not equal to zero, the 100% Build Margin according to equation 13 of the Tool to calculate the emission factor for an electricity system shall be used for $EF_{CO2,ELEC,y}$ [6] ($MWh/1000m^3$)
$EE_{WW,y}$	Embedded electricity in wastewater treatment in year *y*. Optional. ($MWh/1000m^3$)
$EF_{CO2,ELEC,y}$	CO_2 emission factor for grid electricity in year *y* (tCO_2/MWh)
$EF_{DS,y}$	CO_2 emission factor for desalination using Method 2, if applicable, in year *y*; otherwise set to zero ($tCO_2/1000m^3$)

18. Embedded electricity is determined by three formulae, with the first covering water supply components upstream of the end-user (Equation 7), the second accounting for handling of wastewater downstream of the end-user (Equation 8) and the third in the specific case of desalination by reverse osmosis (Equation 9, Paragraph 22):

$$EE_{WS,y} = \sum_{k=1}^{n}\left(\frac{EC_{k,y}}{1-TD_y}\right) \div \left(Q_{WS,k,y} \div \left(1-\frac{WL_y}{Q_{WS,k,y}}\right)\right) \quad \textbf{(7)}$$

$$EE_{WW,y} = \sum_{k=1}^{n}\left(\frac{EC_{k,y}}{1-TD_y}\right) \div \left(Q_{WW,k,y} \div \left(1-\frac{WL_y}{Q_{WW,k,y}}\right)\right) \quad \textbf{(8)}$$

Where:

$EE_{WS,y}$	Embedded electricity in water supply (excluding desalination) in year y ($MWh/1000\ m^3$ water)
$EE_{WW,y}$	Embedded electricity in wastewater treatment in year y ($MWh/1000\ m^3$ water). Optional.
$EE_{DS,y}$	Embedded electricity in water supplied by reverse osmosis desalination, if any, in year y ($MWh/1000\ m^3$ water)
$EC_{k,y}$	Annual electricity consumption by facility *k* in year *y* (MWh)
TD_y	Average annual technical grid losses in year y. A default value of 0.1 shall be used, if no recent data are publicly available or the data cannot be regarded accurate and reliable. TDy shall be set to zero in cases where this Tool is applied in combination with a CDM methodology that already accounts for grid losses associated with energy embedded in water.

[6] As proposed in IEA, 2002 (Kartha, Lazarus and Bosi), reflecting deferrable capacity. Because desalination facilities are among the top consumers in the electricity grid (diurnally and/or in summer on part load or in winter with single-pass configuration) and are typically designed regarding the latest capacity addition/deference.

$Q_{WS,k,y}$	Quantity of water provided by water supply facility *k* in year *y* (1000 m^3)
$Q_{WW,k,y}$	Quantity of water treated by wastewater facility *k* (1000 m^3)
$Q_{DS,k,y}$	Quantity of water provided by reverse osmosis desalination facility *k* in year *y* (1000 m^3)
WL_y	Water losses in year *y* (1000 m^3). Optional, if data are available; otherwise, WL_y shall be set to zero. All real losses but no apparent losses shall be included in WL_y. Real losses shall be established independently of the apparent losses assessment. When data for all water leaving the sources (input into grid) and delivered water (output) are available, the resulting Non-revenue water data can be used to verify real losses and apparent losses.

19. All reported bottom-up loss assessments can be used (most common are 24 Hour Zone Measurement, Minimum Night Flow analysis or Zero-consumption analysis). When bottom-up data is available, the data can be verified with a top-down water balance but bottom-up data alone can be applied with apparent losses remaining unknown or uncertain.

20. In cases involving water supplied by desalination, two mutually exclusive methodologies with different applicability conditions are suggested to determine embedded electricity (Method 1) or CO_2 emission factor for desalination (Method 2).

Method 1 (M1): Desalination facilities using reverse osmosis

21. Method 1 is appropriate for most smaller grids (since reverse osmosis is more efficient and less expensive in smaller unit sizes than thermal technologies) and applies to all reverse osmosis plant sizes, all membrane types and all energy recovery types, if:

(a) All desalination units that can supply the same users are recorded.

(b) Reverse osmosis desalination units supply annually more than 90% of the annual desalted water volume in the water grid (in water volume units).

22. Under M1, the embedded electricity in water supplied by reverse osmosis desalination is determined according to the following equation:

$$EE_{DS,y} = \sum_{k=1}^{n}\left(\frac{EC_{k,y}}{1-TD_y}\right) \div \left(Q_{DS,k,y} \div \left(1-\frac{WL_y}{Q_{DS,k,y}}\right)\right) \quad \textbf{(9)}$$

23. The parameters are defined in the table above.

24. If M1 is not applicable, M2 shall be applied.

Method 2 (M2): Integrated power and water grids with thermal desalination

25. Method 2 applies to all desalination technologies (Multi Stage Flash, Multiple Effect Distillation, Reverse Osmosis), including mixed water desalination technologies, and any combination thereof. It also applies to all power plant technologies, including combined cycle plants with auxiliary firing to the waste heat recovery boiler, and including gas turbine only power plants[7]. Applicability is restricted to cases where:

[7] Water grids are supplied from various desalination plants to maintain supply security. M2 applies especially in Gulf countries where salinity prevents sole use of reverse osmosis. All powerplants and all desalination plants are connected in most cases to the same electricity grid and to the same water grids for supply security (theoretically M1 and M2 can both apply only when there is no connection between the electricity grids supplying reverse osmosis and those supplying thermal desalination plants but their water output goes to the same users).

(a) More than one desalination unit is operated;

(c) The power grids are supplied partially from combined power and desalination plants as well as from electricity-only power plants. Those combined power and desalination plants that comprise extraction/condensing steam turbines to provide lower pressure steam to these desalination units are also the peak load plants, i.e. are used to absorb the daily electricity load variations (while those combined power and desalination plants comprising backpressure turbines and those with auxiliary firing in the Waste Heat Recovery Boiler are not used for the daily load variation).

(d) Power grids are supplied partially from combined power and desalination plants as well as from electricity-only power plants throughout the year (only combinations of desalination technologies and of power plant technologies can maintain energy efficiency during part load periods);

(e) All desalination units that can supply the same users are recorded.

26. There are cases where desalination plants are used in different configurations during part of the year because of more electricity availability in winter or higher water demand in summer. In those cases only M2 shall be used[8].

27. Step 1 is to determine the average net electricity generation efficiency of all electricity-only power plants supplying the grid:

$$\eta_{po} = \frac{\sum FC_y * NCV_y}{\sum EG_y} \qquad \textbf{(10)}$$

Where:

η_{po}	Average net electricity generation efficiency of all power plants producing only electricity to the power grid in year *y*	(ratio)
$FC_{i,y}$	Amount of fossil fuel type *i* consumed by all power plants producing only electricity to the power grid in year *y*	(Mass or volume unit)
$NCV_{i,y}$	Net calorific value (energy content) of fossil fuel type *i* in year *y*	(GJ/mass or volume unit)
EG_y	Net quantity of electricity generated and delivered to the power grid by all power plants producing only electricity in year *y*	(MWh)

28. The thermal energy consumption attributed to the process of desalination is then estimated as follows:

$$HC_{DS,y} = \sum FC_{XX,y} * NCV_{XX,y} - \frac{\sum EG_y}{\eta_{po}} \qquad \textbf{(11)}$$

Where:

$HC_{DS,y}$	Thermal energy used to drive desalination units in year *y*	(GJ)

[8] M2 is conservative because it assumes that the marginal volume of water desalination avoided would result in a respective reduction of operation in the desalination plant and a correspondent increase of operation in the electricity-only power plant. The degree of conservativeness depends on the capacity utilisation of electricity-only powerplants. In most countries electricity-only power plants follow the diurnal variation and their capacity, typically between 30 and 60%, results in lower efficiency than in the desalination plants and M2 reflects this lower efficiency. The assumption that the marginal volume of water desalination avoided results in a change in electricity source to electricity-only plants is physically correct when the desalination units operate at their minimum water to power capacity ratio (or when the operator does not want to change that ratio to maintain efficiency). The applicability condition (that desalination plants with extraction/condensing steam turbines follow diurnal variations) is independent of the reason for conservativeness.

$FC_{XX,y}$ — Amount of fossil fuel type XX consumed by all combined power and desalination plants that comprise extraction/condensing steam turbines to provide lower pressure steam to these desalination units in year *y* (Mass or volume unit)

$NCV_{XX,y}$ — Net calorific value (energy content) of fossil fuel type *i* in year *y* (GJ/mass or volume unit)

EG_y — Net quantity of electricity generated and delivered to the power grid by all combined power and desalination plants that comprise extraction/condensing steam turbines to provide lower pressure steam to these desalination units in year *y* (MWh)

η_{po} — As above

29. The emission factor for energy embedded in water supplied by desalination is calculated as follows:

$$EF_{DS,y} = \frac{HC_{DS,y} * EF_{CO2,XX,y}}{\sum Q_{DS,y}} \qquad \textbf{(12)}$$

Where:

$EF_{DS,y}$ — Desalted water CO_2 emission factor in year *y* ($tCO_2/1000\ m^3$)

$EF_{CO2,XX,y}$ — CO_2 emission factor of fossil fuel type XX in year *y* (tCO_2/GJ)

$Q_{DS,y}$ — Total volume of water desalted in desalination plants supplying the water grid in year *y* ($1000\ m^3$)

$HC_{DS,y}$ — As above

30. The CO_2 emission factor for grid electricity is calculated according to the Tool to calculate the emission factor for an electricity system, or, in the case of small-scale project activities, may be calculated as the weighted average emissions (in tCO_2/MWh) of the current generation mix, in which case the calculations shall be based on data from an official source (where available) and made publicly available.

31. To supplement this Tool, optional calculation templates have been provided and can be used as follows:

Step 1. Define the scope of the water system for which an aggregate CO_2 emission factor for energy embedded in water supplied to end-users is to be determined by specifying the unique water system facilities to be considered. The level of detail depends on the available data. For example, information on each section of the water distribution system can be entered separately, or for all sections of the water distribution system combined.

Step 2. Enter data on each water system facility (including reverse osmosis desalination facilities, when Method 1 below applies), including water flow and electricity use (Water System Facility sheet of Excel file). Either the actual energy consumption of the facility or some estimate of its energy intensity (based on defaults/calculators from Option 1) may be used.

Step 3. In the case that desalination is the source of water and Method 2 below (integrated water/power grids) applies, enter integrated power/water grid data, including fuel inputs and power and water outputs (Desalination sheet of Excel file).

Step 4. Calculate the grid electricity emission factor according to the procedures for combined margin prescribed in the “Tool to Calculate the Emission Factor for an Electricity System”. Small scale project activities may instead use the weighted average emissions (in tCO_2/MWh) of the current generation mix.

Step 5. Calculate the water emission factor, which can then be plugged into end-use CDM methodologies that refer to this tool.

Data and parameters not monitored

32. In addition to the parameters listed in the tables below, the provisions on data and parameters not monitored in the tools referred to in this methodology apply.

Data / parameter:	$EF_{CO2,water,y}$
Data unit:	tCO_2/1000 m^3 water
Description:	Aggregate CO2 emission factor for embedded energy in water supplied to end-users in year y
Source of data:	Calculated
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$EE_{water,y}$
Data unit:	MWh/1000 m^3 water
Description:	Embedded electricity in water supplied to end-users in year y
Source of data:	Calculated
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$EE_{convey,y}$
Data unit:	MWh/1000 m^3 water
Description:	Embedded electricity for conveyance for water supplied to end-users in year y
Source of data:	Calculated
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$EE_{treat,y}$
Data unit:	MWh/1000 m^3 water
Description:	Embedded electricity for water treatment for water supplied to end-users in year y
Source of data:	Calculated
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$EE_{desalt,y}$
Data unit:	MWh/1000 m^3 water
Description:	Embedded electricity for desalination for water supplied to end-users in year y
Source of data:	Calculated
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$EE_{WS,y}$
Data unit:	MWh/1000 m^3 water
Description:	Embedded electricity in water supply (excluding desalination) in year y
Source of data:	Calculated

Measurement procedures (if any):	
Any comment:	

Data / parameter:	$EE_{WW,y}$
Data unit:	MWh/1000 m^3 water
Description:	Embedded electricity in wastewater treatment in year y
Source of data:	Calculated
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$EE_{DS,y}$
Data unit:	MWh/1000 m^3 water
Description:	Embedded electricity in water supplied by desalination using reverse osmosis under Method 1 in year y
Source of data:	Calculated
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$EE_{DS,ff,y}$
Data unit:	GJ/1000 m^3 water
Description:	Embedded (fossil thermal) energy in water supplied by desalination by fossil fuel type under Method 2 in year y
Source of data:	Calculated
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$EF_{DS,y}$
Data unit:	tCO_2/1000 m^3 water
Description:	CO_2 emission factor for desalination in year *y*
Source of data:	Calculated
Measurement procedures (if any):	
Any comment:	

III. MONITORING METHODOLOGY

33. All data collected as part of monitoring should be archived electronically and be kept at least for 2 years after the end of the last crediting period. 100% of the data should be monitored if not indicated otherwise in the tables below. All measurements should be conducted with calibrated measurement equipment according to relevant industry standards.

34. In addition, the monitoring provisions in the tools referred to in this methodology apply.

Option 1 – Default Values

35. For level 1 defaults in Option 1 no monitoring is required.

36. Statistical sampling can be applied to water grids[9] for the calculation of the overall WW_{water}. The minimum sample size shall ensure 90% confidence and 10% uncertainty. For each grid in the sample, all default values shall be confirmed and modifications made when any conveyance or any source or any water treatment component has changed. Statements from water grid operating entities are sufficient. Where water treatment plants and desalination units are used in parallel and the annual water volumes changed, the weighing of level 2 defaults with the respective annual water volumes shall be re-calculated.

Option 2 – Input-Output Approach

37. All parameters in Option 2 shall be updated annually, when the records become available.

Data and parameters monitored

Data / parameter:	$EC_{k,y}$
Data unit:	MWh
Description:	Annual electricity consumption by facility *k* (water supply, desalination or wastewater treatment facility) in year *y*
Source of data:	Utility or government records or official publications
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	TD_y
Data unit:	--
Description:	Average annual technical grid losses in year y.
Source of data:	Utility or government records or official publications
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	$Q_{WS,k,y}$
Data unit:	1000 m^3
Description:	Quantity of water provided by water supply facility *k* in year *y*
Source of data:	Utility or government records or official publications
Measurement procedures (if any):	
Monitoring frequency:	

[9] Most countries have several thousand independent grids, the US has 165,000.

QA/QC procedures:	
Any comment:	

Data / parameter:	$Q_{DS,k,y}$
Data unit:	1000 m^3
Description:	Quantity of water provided by reverse osmosis facility *k* in year *y*. Option 2, M1 only; otherwise set equal to zero.
Source of data:	Utility or government records or official publications
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	$Q_{DS,y}$
Data unit:	1000 m^3
Description:	Total quantity of water desalinated in year *y*. Option 2, M2 only; otherwise set equal to zero.
Source of data:	Utility or government records or official publications
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	$Q_{WW,k,y}$
Data unit:	1000 m^3
Description:	Quantity of water treated by wastewater facility *k* in year *y*
Source of data:	Utility or government records or official publications
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	WL_y
Data unit:	1000 m^3
Description:	Water losses in year *y*
Source of data:	Utility or government records or official publications
Measurement procedures (if any):	
Monitoring frequency:	annually
QA/QC procedures:	
Any comment:	Water losses are calculated whenever models are used to assure water quality (chlorine levels), to define pump schedules (efficiency) or to design maintenance programmes. All types of distribution grid models used also calculate the real water losses as a by-product. When such models are used online (with SCADAs) loss results for these grids can be used conservatively for all grids in the region.

Data / parameter:	$FC_{XX,k,y}$
Data unit:	ton, m^3
Description:	Amount of fossil fuel type XX (e.g., $FC_{NG,k,y}$ for natural gas) combusted by facility *k* in year *y*
Source of data:	Utility or government records or official publications
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	$NCV_{XX,y}$
Data unit:	GJ/mass or volume
Description:	Net calorific value (energy content) of fossil fuel type XX in year *y*
Source of data:	
Measurement procedures (if any):	
Monitoring frequency:	Once per crediting period
QA/QC procedures:	
Any comment:	The gross calorific value (GCV) of the fuel can be used, if gross calorific values are provided by the data sources used. Make sure that in such cases also a gross calorific value basis is used for CO2 emission factor.

Data / parameter:	$EG_{k,y}$
Data unit:	MWh
Description:	Net quantity of electricity generated and delivered to the power grid in plant *k* in year *y*
Source of data:	Utility or government records or official publications
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	η_{po}
Data unit:	--
Description:	Average net electricity generation efficiency of all power plants producing only electricity to the power grid in year *y*
Source of data:	calculated
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	

Data / parameter:	n
Data unit:	--
Description:	Number of water treatment steps in plant *j*

Source of data:	
Measurement procedures (if any):	annually
Monitoring frequency:	
QA/QC procedures:	
Any comment:	All treatment process steps for which default emission factor values are used in the calculation of $EE_{treat,y}$ are identified and all steps that were not in operation for more than ten days are excluded for the year *y*. When no changes in water sources, or mayor components of conveyance, treatment or desalination have occurred since the previous year, the results of equations 1 to 4 shall be re-used. When changes occurred and the result is within the 90/10 precision rule, the result shall be used directly. When the result is outside of the precision rule, the entirety of the water grids in the region have to be re-assessed for their technology components and the respective default values applied.

Data / parameter:	m
Data unit:	--
Description:	Number of water treatment plants supplying the water grid
Source of data:	
Measurement procedures (if any):	
Monitoring frequency:	
QA/QC procedures:	
Any comment:	All treatment plants that can supply the water grid are recorded and their annual production quantities are monitored. No division of the quantities for different steps WTP are monitored.

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ANNEX I. DEFINITIONS

General Terms

Embedded energy (also referred to as energy intensity or embodied energy) is the total amount of energy, calculated on a whole-system basis, required for the use of a given amount of water in a specific location.

Water Cycle Components (source: Cooley & Wilkinson, in press)

Stage 1: **Source extraction** refers to the extraction of water from its source to the surface. Energy requirements for water source extraction depend upon the location of the water relative to the surface and the method of extraction. Using this definition, the energy intensity of water supply for water that is already at the surface, e.g., seawater, recycled water, or river water, is zero. **Water conveyance** refers to the transport of untreated water through aqueducts, canals, and pipelines from its source to a water treatment facility or directly to an end user if the end user uses raw water. Energy requirements for conveyance depend primarily on the distance and net elevation that it is pumped, as well as pump efficiency.

Stage 2: **Water treatment** refers to processes and technologies that treat water prior to its distribution to homes and businesses, including desalination. The energy requirements for treatment depend upon the quality of the source water and the technology employed to treat that water.

Stage 3: **Water distribution** refers to the transport of treated water (both potable and non-potable water) to the customer. Like conveyance, the energy intensity of distribution depends largely on the distance and elevation that water is pumped, as well as pump efficiency.

Stage 4: **Customer end-use** of water refers to the multitude of ways that we use water in residential, commercial, industrial, institutional, and agricultural settings, which include for personal hygiene, dish and clothes washing, landscape and crop irrigation, process water, and equipment cooling. Energy use associated with customer water end use is typically associated with heating, cooling, water treatment (e.g., filtering and softening), circulation, and supplemental pressurization in high rises.

Stage 5: **Wastewater collection** refers to the movement of untreated wastewater from the end user to the wastewater treatment facility. The energy requirements for wastewater collection depend upon local geography and pump efficiency. **Wastewater treatment** refers to the application of biological, physical, and/or chemical processes to bring wastewater to discharge standards. The energy requirements for wastewater treatment depend upon the level of treatment and, because wastewater must be pumped throughout the treatment facility, pump efficiency. **Wastewater discharge** refers to the movement of treated wastewater from the wastewater treatment facility to the receiving waters. Energy requirements for wastewater discharge depend upon local geography and pump efficiency.

Desalination Technologies & Parameters (source: Sommariva, 2010)

An electricity system is defined by the spatial extent of the power plants that are physically connected through transmission and distribution lines to the project activity and that can be dispatched without significant transmission constraints.

Power plant/unit. A power plant/unit is a facility that generates electric power. Several power units at one site comprise one power plant, whereas a power unit is characterized by the fact that it can operate independently from other power units at the same site. Where several identical power units (i.e. with the same capacity, age and efficiency) are installed at one site, they may be considered as one single power unit.

Desalination plant. A desalination plant is a facility that treats seawater or brackish water by removing impurities either through evaporation or through reverse osmosis. A desalination plant consists of a series of desalination units that share the supply of power or thermal energy.

Cogeneration. Cogeneration is a power plant type where thermal energy is used to drive gas and steam turbines and where thermal energy from these turbines is used to provide thermal energy for other purposes than power generation.

Built margin. The built margin for desalination compares the average efficiency of all power only plants to those of all desalination plants running with condensation/ extraction turbine steam from combined cycle power plants. The built margin is lower than the operating margin because power only plants are typically run at low part loads. The built margin can only be calculated when power only plants generate at least 3% of all electricity in the power grid.

Operating margin. The operating margin for desalination is the fuel consumed for the marginal volume of desalted water in an individual desalination plant. The operating margin is more accurate than the built margin when the individual desalination plant following the electricity grid load variation is known for all periods of a year.

Backpressure turbine. A backpressure turbine is a steam turbine where steam leaves the turbine outlet as steam at a sufficient pressure to provide thermal energy before entering a condensor. Backpressure turbines in desalination plants are typically used to provide baseload power in a power grid because their efficiency decline more at part loads than condensing/extraction turbines.

Condensing/extraction turbine. A condensing/extraction turbine is a steam turbine where steam leaves the outlet at vacuum pressure (<0.1bar) and enters a condensor, while part of the steam is extracted at a higher pressure to provide other thermal energy loads. Condensing/extraction turbines in desalination plants are typically used to follow the daily load variations in a power grid.

Gas turbine. A gas turbine consists of a compressor, an expansion turbine and combustion chamber in between. Gas turbines burn natural gas or oil. The exhaust from a gas turbine typically enters a heat recovery steam generator, generating steam to drive a steam turbine or to supply thermal energy to a desalination plant. Gas turbines are used to follow the daily load variations in a power grid.

Desalter. A desalter is a desalination unit that uses evaporation of seawater over a series of tube bundle heat exchangers driven by steam from a power plant.

Multi stage flash technology. Multi stage flash (MSF) desalination uses a series 12 to 35 stages of evaporation. At each stage part of the brine flow flashes into steam when heated by the returning brine flow. MSF units are the largest desalination units and are dominantly used in Middle East.

Multiple effect desalination. Multiple effect desalination (MED) technology involves evaporation from a falling seawater film in contact with a heat transfer surface. MED technology is used increasingly since 2000. It is more efficient than MSF but cannot be built in the same sizes.

Reverse osmosis. Reverse Osmosis (RO) is a desalination technology were water is pumped through a membrane that separates seawater from permeate. Reverse osmosis membranes are of two categories, hollow fine fibres and spiral wound fibres.

Load duration curves. A load duration curve consists of a ranked daily or hourly water or power demand over a year from highest to lowest value. Both water and power demand peak in summer and are lowest in winter.

Water to power capacity ratio. The ratio between volume of desalted water per MW power capacity in cogeneration power plants. Because of load duration curves, different desalination technologies, MSF, MED and RO are combined so that their differences in Water to power ratio result in the lowest fuel consumption across the year.

Water Treatment Technologies & Parameters (source: Binnie and Kimber, 2009)

Water mains. Mains are pipes and open channels that convey water to distribution points.

Maximum pumping efficiency. Centrifugal pumps are single or multi-stage pumps using electric power. The maximum efficiency reflects the best available pumps and this maximum efficiency increases with pump size.

Adsorption. Adsorption is used to remove a variety of organic and anorganic trace substances with activated carbon.

Aeration. Aeration comprises a variety of installation that inject air into freshwater in order to remove dissolved gases, notably carbonic acid but also other organic substances (and lowering iron and manganese).

Dissolved air flotation. A process in which air is dissolved into water under high pressure and is subsequently released into the bottom of a treatment unit to float solids. On release, the lower pressure in the unit results in the formation of bubbles that collect particles as thy rise to the surface. The floated particles are then skimmed for subsequent processing. This process is effective in removing low-density solids and algae.

Chlorination. Chlorine disinfection consists of an injection of chlorine gas, typically at the end of the treatment. Chlorine gas has a high oxidation potential and eliminates biological contents in high quality groundwater.

Chlorine dioxide. Chlorine dioxide gas is an oxidation agent like chlorine. Chlorine dioxide is used in larger water treatment plants, especially for surface water treatment.

UV disinfection. Ultraviolet radiation is applied to destroy bacteria and micro-organisms. Minimum radiation strength is regulated for flow volumes.

Ozonation. Ozone is used as an disinfectant, mainly for surface water. Ozone concentrations are regulated. Its generation in plants consumes electrical energy.

Slow sand filtration. Filtration with gravitational flow through a bed of sand with a biologically active mat on the sand surface. Mostly used for surface water after flocculation and before disinfection. After two weeks to three months, the upper sand layer is replaced. . Water flow rates up to 12 $m^3/h/m^2$ are used, frequently used in rural areas.

Rapid gravity filtration. Rapid gravity filtration uses a small sand layer that his periodically cleaned through backwashing with water and air. Water flow rates up to 30 $m^3/h/m^2$ are used.

Backwash water treatment. Periodic cleaning of sand and membrane filters leaves backwash waters that can be dumped, re-circled or treated in separate filtration units.

Microfiltration. Microfiltration is the process of filtration with micrometer sized filter pores (<0.1 μm).

Ultrafiltration. Ultrafiltration is applied to separate pollution such as viruses and uses a filter medium between pores of 0.2 and 0.01 μm. Frequently used for high quality groundwater.

Nanofiltration. Nanofiltration uses spiral-wound and hollow-fiber membrane filters below 0.01 μm pores. Besides the filtration effects, the membrane also separates ions and reduces trace metals.

Activated carbon. Activated carbon is char activated with oxidizing gases to create a porous absorbent surface which removes mostly organic matter from groundwater or surface water. Powdered activated carbon is most frequent and is not regenerated (with steam or solvent) but disposed. Granular activated carbon is typically regenerated and it used in few countries. Fixed-bed contactors in various flow configurations are contain activated carbon columns of 2-5 meters height.

Natural organic matter (NOM). A heterogeneous mixture of organic matter that occurs ubiquitously in both surface water and groundwater, although its magnitude and character differ from source to source. Natural organic matter contributes to the colour of a water, and it functions as disinfection by-product precursors in the presence of such disinfectants as chlorine. Humic substances (e.g. fulvic acid) represent a significant fraction of natural organic matter in surface water sources.

Nephelometric turbidity unit (NTU) a unit for expressing the cloudiness (turbidity) of a sample as measured with the amount of light scattered by particles in a water sample.

Sludge treatment. Sludge from clarification and water filter washwater contains 1 – 5% solids and is dewatered, thickened, centrifuged or dried and then landfilled.

Sludge sedimentation. Sludge are solids settled out from wastewater, but still containing high percentage of water. Sedimentation is the removal of settleable solids in tanks, ponds or reservoirs.

Thermal sludge treatment. The heating of wastewater sludge in order to improve the dewaterability. Can comprise heat drying, pyrolysis or wet air oxidation.

Mechanical sludge treatment. Mechanical sludge treatment uses the following four types of equipment.

Chamber filter press (also filter plate press). Chamber filters operate in batch mode, applying 12-15 bar pushing water through a series of vertical plates in a frame, from where built up press cake is removed in each cycle. After up to 200 cycles the filter material is cleaned with a chemical process.

Screen filter press (also filter belt press). Screen filters operate continuously and under pressure or under vacuum. Sludge volumes between 2 and 30 m^3/h is treated and reach 3 -9% dry matter content.

Vacuum filtration. Vacuum filters are a filter cloth on a drum with a vacuum to draw water inside.

Centrifugal de-watering. Solid bowl centrifuges contain a rotating screw pressing sludge through a bowl. Units between 1 and 200 m^3/h are used and reach 20 – 35% dried sludge concentration.

Water Losses (source: Farley and Trow, 2003)

Authorized consumption. Authorized consumption is the annual volume of metered and/or un-metered water taken by registered costumers, the water supplier and others who are implicitly or explicitly authorized to do so. It includes water exported, and leaks and overflows after the point of customer metering.

Minimum night flow. In a specific zone of the water grid, the minimum flow occurs between 2 and 4 am and corresponds to the leakage in this zone. It is established with flowmeters in the outlet of storage tanks to monitor trends in leakage rates and inform grid maintenance.

Non-revenue water. Non-revenue water is the difference between system input volume and billed authorized consumption. Non-revenue water consists of unbilled authorized consumption and water losses.

Water losses. Water losses are the difference between system input volume and authorized consumption, and consists of apparent losses and real losses.

Apparent losses. Apparent losses consist of unauthorized consumption and all types of metering inaccuracies.

Real losses. Real losses are the annual volumes lost through all types of leaks, bursts and overflow on mains, service reservoirs and service connections, up to the point of customer metering.

System input volume. System input volume is the annual volume input to that part of the water supply system.

Zero consumption. Smaller units of zones are shut off until zero consumption is reached. This method allows to localize leaks and bursts, and measures leakage with high accuracy. This is produced with automatised procedures in advanced grids.

Section D. Explanations / justifications to the proposed new baseline and monitoring methodology

Intentionally left blank

Selected approach from paragraph 48 of the CDM modalities and procedures

38.

Definitions

39.

Applicability conditions

40.

Project boundary

41.

Identification of the baseline scenario

42.

Additionality

43.

Baseline emissions

44.

Project emissions

45.

Leakage

46.

Emission reductions

47.

Changes required for methodology implementation in 2nd and 3rd crediting periods

48.

Monitoring methodology, including data and parameters not monitored

49.

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History of the document

Version	Date	Nature of revision(s)
03.1	20 May 2008	Second bullet of formatting instructions changed to refer to Sections C and D, rather than Section B; Change in numbering of paragraphs.
03	EB 38, Annex 6 14 March 2008	Revision of the structure of the document to reflect the sections of a standard approved baseline methodology. Section A. Recommendation by the Methodological Panel Section B. Summary and applicability of the baseline and monitoring methodology Section C. Proposed new baseline and monitoring methodology Section D. Explanations / justifications to the proposed new baseline and monitoring methodology
02	EB 32, Annex 17 22 June 2007	The form "CDM-NM" was merged with the recommendation form "F-CDM-NMmp". The F-CDM-NMmp discontinued to be used. The change was adopted in line with the revised "Procedures for submission and consideration of a proposed new methodology" in order to simplify and streamline the process of consideration of new methodologies.
01	EB 08, Annex 02 29 September 2006	Initial adoption

END of NM Form

Default values

Conveyance and Distribution

Larger water grids are often managed with software models to calculate the best operating schedules of pumps and other grid components. The majority of grids however are still calculated by hand when designing grid extensions or maintenance programmes.
The topology of conveyance and distribution varies for each grid and it is not possible to define widely used distribution subunits. All grids can be manually calculated with the following defaults. These are versatile and require a minimum of information, geographic distances, flows or mains diameters. However using these defaults needs some skill in simplifying the actual grid to limit the amount of calculation. For large water grids, these defaults allow an approximation of the conveyance side, but large distribution grids cannot be analyzed with manual calculation.

Defaults for pumping energy *Spd*

Average water flow (m^3/s)	Water mains diameter DN (mm)	Specific horizontal pumping energy ***Spd*** (Pa/km)
0.004	80	98,000
0.0063	100	73,550
0.0098	125	56,880
0.0150	150	50,000
0.0283	200	39,000
0.0466	250	36,300
0.0707	300	27,500
0.101	350	26,480
0.138	400	24,500
0.236	500	22,550
0.368	600	21,570
0.539	700	20,594
0.779	800	20,594
1.150	900	20,594
1.375	1000	20,594
	>1000	20,594

Defaults for maximum pump efficiency

Average flow (m^3/s)	maximum pump efficiency η_{max}
> 5	0.94
> 0.5	0.90
> 0.2	0.88
> 0.1	0.86
> 0.05	0.83
> 0.02	0.78

Water treatment

The following treatment stages and processes are present in various combinations in all water treatment plants, depending on the properties of the water at source. These defaults are at the lower end of the typical range of energy consumption. The maximum data is included only to control Options 2 and 3 results.

Stage	Default specific electricity consumption (Wh/m^3)	Max. specific electricity consumption (Wh/m^3)
Removal of Fe and Mn	0	
Softening	0	
Flocculation, coagulation	0	
Dissolved air flotation	40	
Adsorption	0.2	0.6
Aeration	5.0	130
Chlorine dioxide	0.3	0.6
Chlorination	0.1	0.2
UV disinfection	8.0	20
Ozonation	7.0	60
slow sand filtration, activated carbon, rapid gravity filtration	0.2	0.5
Microfiltration	40	200
Ultrafiltration	30	300
Nanofiltration	300	500
Reverse osmosis	300	800

Ultrafiltration

		Water properties:			
		<1 NTU, <1 DOC	<1 NTU, 1< DOC <5	<1NTU<5, <1 DOC	<1NTU<5, <1DOC<5
Ultrafiltration	(kWh/m^3)	0.1	0.15	0.2	0.3

Sludge drying

Type	Spec. consumption (kWh/m^3sludge)	Max. spec. consumption (kWh/m^3sludge)	Spec. consumption (kWh/m^3 thicked sludge)	Max. spec. consumption (kWh/m^3 thicked sludge)
chamber filter press	1.0	1.5		
screen filter press	1.3	1.8		
plate pressing	1.0	1.5		
vacuum filter			6.0	12.0
Centrifuges	1.2	2.0	3.0	4.0

Sludge dewatering

Type	Default consumption (kWh/m^3 water extracted)	Max. consumption (kWh/m^3 water extracted)
sedimentation	0.014	0.02
mechanical	2.8	5.6
thermal	1200	1400

Sand filter backwash water treatment

Type	Default consumption (kWh/m^3)	Max. spec. consumption (kWh/m^3)
Microfiltration Ultrafiltration Nanofiltration	0.2	1.0

Desalination – Reverse Osmosis

	Energy Recovery Technology		
	Work (pressure) exchanger	Turbocharger	Pelton turbine
Water Pre-treatment Technology	MWh/m^3	MWh/m^3	MWh/m^3
Floc gravity filtration + static mixer	3.84	4.32	4.59
Floc gravity filtration + floc basins	4.18	4.30	4.57
Sedimentation + filtration	4.22	4.70	4.97
Flotation + filtration	4.22	4.70	4.97
Membrane filtration (MF, UF or NF)	4.06	4.54	4.81
Flotation + membrane filtration	4.37	4.86	5.13

Correction for seawater salinity

Specific electricity consumption changes with seawater salinity

Total Dissolved Solids (ppm, mg/l)	B (MWh/m^3)
34,000 - 36,000	-0.44
36,000 - 38,000	-0.22
38,000 - 40,000	0.00
40,000 - 42,000	0.22
42,000 - 44,000	0.44
44,000 - 46,000	0.66
46,000 - 48,000	0.88
48,000 - 50,000	

Correction for plant size

Specific electricity consumption for small units

Design desalted water capacity (m^3/d)	C (kWh/m^3)
< 10,000	-0.2
< 8,000	-0.4
< 6,000	-0.6
< 4,000	-0.8
< 2,000	-1.0
< 500	not credited

Abbreviations and Units

Btu	British thermal unit	=	1,055 joules
GJ	Gigajoule		
kWh	kilowatt hour		
MWh	Megawatt hour		
m^3	cubic meter		
m^3/s	cubic meter per second		
mg/l	milligram per litre		
MIG	million imperial gallon	=	4,546 cubic meter
Pa	Pascal	=	1 newton per square meter
ppm	parts per million		

Desalted Water Emission Factor in United Arab Emirates according to Tool to Calculate the Emission Factor for Energy Embedded in Water Delivered to End-Users

Option 2 Method 2, data reported for 2006

Table: All electricity-only plants operated in 2006 in UAE

Powerplant	Fuel used (MBTu)	Gross electricity produced (MWh)
Abu Dhabi Gas Turbines	1,450,791	95,489
Al Ain	690,914	45,965
Madinat Zayed	1,266,367	96,654
Sum 2006	3,408,072	238,108

Source: www.adwec.ae

The published records of the national utility company reports total thermal energy input in MBTu for all powerplants not in fuel volume.

Equation 10 in Tool:

$$\text{Average efficiency electricity-only} = \frac{238{,}108 \text{ MWh} \times 3.6}{3{,}408{,}072 \text{ MBTu} \times 1.05581} = 0.2382 = \eta_{po}$$

Table: All desalination plants with condensing/extraction turbines

Powerplant	Fuel used (MBTu)	Gross electricity produced (MWh)	Desalted water produced (MIG)
Taweelah B	54,710,727	3,533,273	22,343
UAN 1 – 6	32,732,381	1,565,552	7,229
UAN 7 – 8	17,856,808	1,030,851	4,435
UAN 9 – 10	6,263,281	347,801	1,825
Sum 2006	111,563,197	6,477,477	35,832

Source: www.adwec.ae

Equation 11 in Tool:

$$\text{Thermal energy to Desalination} = \frac{111{,}563{,}197 \text{ MBTu} \times 1.05562}{3.6} - \frac{6{,}477{,}477 \text{ MWh}}{0.2382} =$$

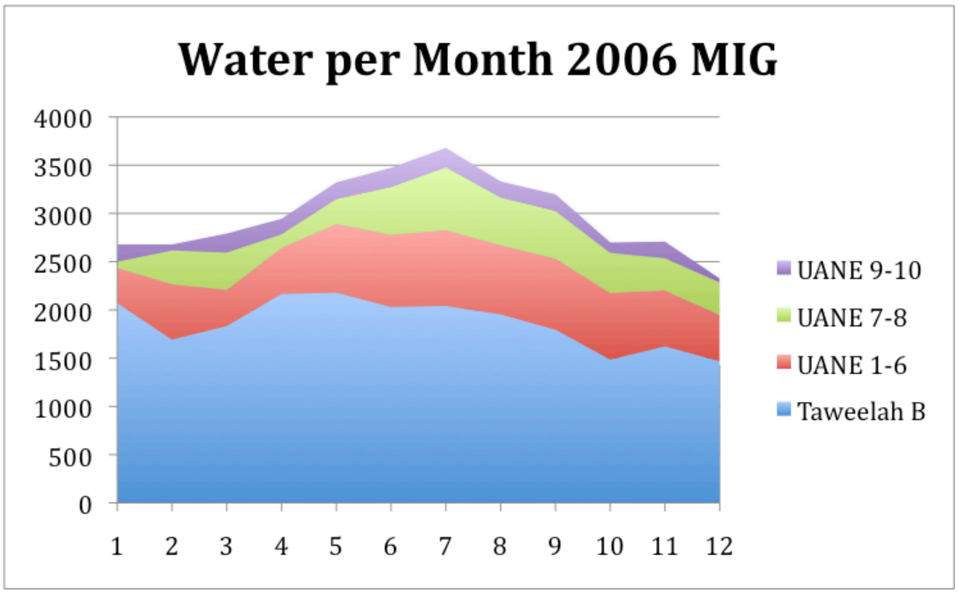
$$= 5{,}528{,}395 \text{ MWh}_{thermal}$$

Equation 12 in Tool:

$$\text{Desalination EF} = \frac{5{,}528{,}395 \text{ MWh}_{th} \times 50.1 \text{ tCO2/GJ} \times 3.6}{162.87 \text{ mio m}^3 \times 1{,}000{,}000} = \underline{6.12 \text{ tCO}_2/1000\text{m}^3}$$

This is a very conservative estimate based on publicly available information. By comparison a suitable engineering approach yields 16.66 $tCO_2/1000m^3$. However, this accurate emission factor can not be established without steam flow data from desalters. While the data to calculate the accurate result exists automatically because it is not possible to operate desalination plants without this data, the computerized control system records in the desalination plants are not made publicly available by the utility companies or the regulator ADWEC. The barrier to calculating the more accurate emission factor is the confidentially of data among the seven private desalination plant operating companies. This situation is typical in OPEC countries, where foreign investors receive the fuel for free and get paid per water output. Water demand is rising 10% p.a. in the UAE. ~6 bn US$ have been invested in new desalination capacity in the last 10 years in UAE, corresponding to 5 mio m^3 per day of desalination capacity.

Graph: Monthly desalination in plants with extraction/condensing turbines in operation in UAE (those for diurnal load variation)



Source: www.adwec.ae

UANE	Umm Al Nar East	geographic location 15 km north of Abu Dhabi
	Taweelah	geographic location 35 km north of Abu Dhabi

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