Annex – Structure and explanation of theoretical cost model

Name of matrix/vector (dimensions)	**Definition**	**Description**
$\underset{(n\times 1)}{a_t} \quad t=\{0,1\}$	Input	Corporate tax rate in a given *country (n)* in given *time period (t)*
$\underset{(n\times 1)}{b}$	Input	Discount rate in a given *country (n)*
$\underset{(n\times s)}{AS_t} \quad t=\{0,1\}$	Input	Gross annual salary (US$) for a given *facility staff type (s)* in a given *country (n)* in given *time period (t)*
$\underset{(n\times 1)}{c_t} \quad t=\{0,1\}$	Input	Income tax rate of facility employees in a given *country (n)* in given *time period (t)* {needed if we consider net salary in calculations (would influence tot cost (and MEH))}
$\underset{(n\times 1)}{d_t} \quad t=\{0,1\}$	Input	Employee benefits (as % of salary) in a given *country (n)* in given *time period (t)*
$\underset{(n\times s)}{B_t} \quad t=\{0,1\}$	Input	Overhead costs (as % of salary) for a given *facility staff type (s)* in a given *country (n)* in given *time period (t)*
$\underset{(n\times s)}{C_t} \quad t=\{0,1\}$	$C_t[n,s]=AS_t[n,s]*(1+d_t[n]+B_t[n,s])$	Loaded salary in a given *country (n)* in given *time period (t)* {if we use net salary, AS[n,s] will be replaced by the net salary matrix}
$\underset{(n\times s)}{D_t} \quad t=\{0,1\}$	$D_t[n,s]=\frac{C_t[n,s]}{C_t[n,1]}$	Equivalent managerial hours (EMH) calculated as depending on the loaded salary for a given *facility staff type (s)* in a given *country (n)* in given *time period (t)*
$\underset{(z\times t)}{E} \quad t=\{0,1\}$	Input	Hours of work required for a given *initial action (p)* and *final action (q)* for a given *facility staff type (s)* in given *time period (t), where z=(p+q)*s*

$\underset{(n\times(p+q))}{F_t}$ $t=\{0,1\}$	$F_t[n,i]$ $=E[i,t]+(E[i+1,t]*D_t[n,2])$ $+(E[i+2,t]*D_t[n,3])+(E[i+3,t]*D_t[n,4])$ $i=\{1,5,9,13,\ldots,z-3\}$	Equivalent managerial hours of work needed for a given *initial (p)* and *final action (q)* in a given *country (n)* in given *time period (t), where z=(p+q)*s*
$\underset{(s\times(m+c+e))}{G_t}$ $t=\{0,1\}$	Input	Hours of work required by given *facility staff type (s)* for given *measuring (m), calculating (c)* or *estimating actions (e)* by facility staff to assess substances emissions in given *time period (t)* (same concept as matrix E but with different actions)
$\underset{(n\times(m+c+e))}{HH_t}$ $t=\{0,1\}$	$HH_t[n,i]$ $=G_t[1,i]+(G_t[2,i]*D_t[n,2])$ $+(G_t[3,i]*D_t[n,3])+(G_t[4,i]*D_t[n,4])$ $i=\{1,\ldots,(m+c+e)\}$	Equivalent managerial hours of work needed for given *measuring (m), calculating (c)* or *estimating actions (e)* by facility staff to assess substances emissions in a given *country (n)* and a given *time period (t)* (same concept as matrix F but with different actions)
$\underset{((m+c+e)\times n)}{I_t}$ $t=\{0,1\}$	$=HH_t'$	
$\underset{(n\times1)}{gtotal_t}$ $t=\{0,1\}$	$=ga_t+gw_t+gl_t+gww_t+gt_t+gh_t+gn_t$	Total number of pollutants reported by facilities in a given *country (n)* in given *time period (t)*
$\underset{(n\times1)}{j_0}$	$j_0[n]=\sum_{j=1}^{p}F_0[n,j]$	Total number of EMHs needed for initial actions by facility staff in a given *country (n)* only in the first time period (t=0)
$\underset{(n\times1)}{k_0}$	$k_0[n]=j_0[n]*C_0[n,1]$	Cost of initial actions by facility staff per facility in a given *country (n)* only in the first time period (t=0)
$\underset{(n\times1)}{l_0}$	$l_0[n]=k_0[n]*w_0[n]$	Total cost of initial actions by facility staff in a given *country (n)* only in the first time period (t=0) (including all facilities)
$\underset{(n\times1)}{o_t}$ $t=\{0,1\}$	$o_t[n]=\sum_{j=p+1}^{p+q}F_t[n,j]$	Same concept as vector j_0 with the difference that this vector monitors final actions by facility staff
$\underset{(n\times1)}{n_t}$ $t=\{0,1\}$	$n_t[n]=o_t[n]*C_t[n,1]$	Same concept as vector k_0 with the difference that this vector monitors final actions by facility staff

$\underset{(n\times 1)}{p_t} \quad t=\{0,1\}$	$p_t[n]=n_t[n]*x_t[n]$	Same concept as vector l_0 with the difference that this vector monitors final actions by facility staff
$\underset{(1\times n)}{h_tT} \quad t=\{0,1\}$	$=ha_t+hw_t+hl_t+hww_t+ht_t+hh_t+hn_t$	EMHs in a given *country (n)* in given *time period (t)* using the employee threshold approach
$\underset{(n\times 1)}{h_t} \quad t=\{0,1\}$	$=(h_tT)'$	
$\underset{(n\times 1)}{q_t} \quad t=\{0,1\}$	$q_t[n]=h_t[n]*C_t[n,1]$	Total cost for MCE actions by facility staff in a given *country (n)* in given *time period (t)*
$\underset{(1\times n)}{i_tT} \quad t=\{0,1\}$	$=ia_t+iw_t+il_t+iww_t+it_t+ih_t+in_t$	Same concept as vector h_tT with the difference that this vector uses the capacity threshold approach
$\underset{(n\times 1)}{i_t} \quad t=\{0,1\}$	$=(i_tT)'$	
$\underset{(n\times 1)}{r_t} \quad t=\{0,1\}$	$r_t[n]=i_t[n]*C_t[n,1]$	Same concept as vector q_t with the difference that this vector uses the capacity threshold approach
$\underset{(n\times 1)}{s_t} \quad t=\{0,1\}$	$=l_t+p_t+q_t$ $(NB: l_1=0)$	Total national facility cost in a given *country (n)* in given *time period (t)* using the employee threshold approach
$\underset{(n\times 1)}{t_t} \quad t=\{0,1\}$	$=l_t+p_t+r_t$ $(NB: l_1=0)$	Same concept as vector s_t with the difference that this vector uses the capacity threshold approach
$\underset{(u\times v)}{A1}$	Input	For each *activity (v)*, a '1' is assigned to a cell to indicate that a given *substance (u)* <u>is</u> likely to be released into air; <u>otherwise</u>, a '0' is assigned. {Information gathered from EPER data available for 2001 and Aarhus Protocol Guidance}
$\underset{(v\times u)}{A1T}$	$A1'$	
$\underset{(u\times v)}{W1}$	Input	Same concept as matrix A1 with the difference that it relates to water emissions
$\underset{(v\times u)}{W1T}$	$W1'$	
$\underset{(u\times v)}{L1}$	Input	Same concept as matrix A1 with the difference that it relates to land emissions

$\underset{(v\times u)}{L1T}$	$L1'$	
$\underset{(u\times v)}{WW1}$	Input	Same concept as matrix A1 with the difference that it relates to transfers of water waste
$\underset{(v\times u)}{WW1T}$	$WW1'$	
$\underset{(u\times v)}{T1}$	Input	Same concept as matrix A1 with the difference that it relates to transfers of waste under a pollutant-specific regime
$\underset{(v\times u)}{T1T}$	$T1'$	
$\underset{(u\times v)}{H1}$	Input	Same concept as matrix A1 with the difference that it relates to transfers of hazardous waste under a waste-specific regime
$\underset{(v\times u)}{H1T}$	$H1'$	
$\underset{(u\times v)}{N1}$	Input	Same concept as matrix A1 with the difference that it relates to transfers of non-hazardous waste under a waste-specific regime
$\underset{(v\times u)}{N1T}$	$N1'$	
$\underset{(n\times \ell)}{A2M}$	Input	Records a given *legal commitment under an MEA (l)* in a given *country (n)*
$\underset{(u\times \ell)}{A3M}$	Input	Records a given *substance (u)* in a given *legal commitment under an MEA (l)*
$\underset{(\ell\times u)}{A3MT}$	$A3M'$	
$\underset{(n\times u)}{A4M}$	$= A2M \cdot A3MT$	A ‘0’ in a cell indicates that a given *country (n)* does not monitor a given *substance (u)*; otherwise, a number greater than zero indicates that the country does monitor that substance under an MEA
$\underset{(n\times o)}{A2N}$	Input	Same concept as matrix A2M with the difference that this matrix contains information about a given *national PRTR (o)* in a given *country (n)*
$\underset{(u\times o)}{A3N}$	Input	Same concept as matrix A3M with the difference that this matrix contains information mapping a given *national PRTR (o)* to a given *country (n)*

$\underset{(o\times u)}{A3NT}$	$= A3N'$	
$\underset{(n\times u)}{A4N}$	$= A2N \cdot A3NT$	A '0' in a cell indicates that a given *country (n)* does not monitor a given *substance (u)*; otherwise, a number greater than zero indicates that the country does monitor that substance under a national PRTR
$\underset{(n\times u)}{A4L}$	Input	A '1' is assigned to a cell to indicate that a given *country (n)* does monitor a given *substance (u)* under a national licensing system; otherwise, a '0' is assigned
$\underset{(n\times u)}{A4}$	$= A4M + A4N + A4L$	A '0' in a cell indicates that a given *country (n)* does not monitor a given *substance (u)*; otherwise, a number greater than zero indicates that the country does monitor that substance under an MEA, a national PRTR or a licensing system
$\underset{(n\times u)}{A5}$	If *A4[n,u]>0*, then *A5[n,u]=1* Otherwise, *A5[n,u]=0*	A '0' in a cell indicates that a given *country (n)* does not monitor a given *substance (u)*; otherwise, a '1' indicates that the country does monitor that substance (under an MEA, a national PRTR or a licensing system)
$\underset{(u\times n)}{A6}$	$= A5'$	
$\underset{(u\times n)}{A7E}$	$A7E[,n] = m1 - A6[,n]$	For the employee threshold approach, this matrix maps a given *substance (u)* still required to be monitored to comply with the Aarhus ACP to a given *country (n)*. NB this applies to those substances that are not monitored elsewhere by a given country; and vector m1 becomes another vector if we consider another medium
$\underset{(u\times n)}{A71E}$	If *A7E[n,u]=1*, then *A71E[n,u]=1* Otherwise, *A71E[n,u]=0*	Same concept as matrix A7E mapped into binary combinations [0,1]
$\underset{(u\times n)}{A7C}$	$A7C[,n] = m2 - A6[,n]$	Same concept as matrix A7E with the difference that this matrix refers to the capacity threshold approach. NB vector m2 becomes another vector if we consider another medium
$\underset{(u\times n)}{A71C}$	If *A7C[n,u]=1*, then *A71C[n,u]=1*; Otherwise, *A71C[n,u]=0*	Same concept as matrix A71E, but this matrix refers to the capacity threshold approach
$\underset{((m+c+e)\times u)}{A8_t} \quad t = \{0,1\}$	Input	Assigns a '0' to indicate that a given *measurement (m)*, *calculation (c)*

		or *estimation action (e)* is not required for a *given substance (u)* in a given *time period (t)*; otherwise, assigns a ‘1’ if that MCE action is required
$\underset{(n\times u)}{A9_t} \quad t=\{0,1\}$	$= Z_t \cdot A1T$	Total number of facilities monitoring a *given substance (u)* in a *given country (n)* in a given *time period (t)*
$\underset{(n\times 1)}{ga_t} \quad t=\{0,1\}$	$ga_t[n]=\sum_{j=1}^{u} A9_t[n,j]$	Total number of facilities monitoring the sum of all substances in a *given country (n)* in a given *time period (t)*
$\underset{(u\times n)}{A10_t} \quad t=\{0,1\}$	$= A9'_t$	
$\underset{(u\times n)}{A11E_t} \quad t=\{0,1\}$	$A11E_t[u,n]=A10_t[u,n] * A71E[u,n]$	Total number of facilities under the employee threshold approach that are required by the Aarhus ACP to monitor a *given substance (u)* not yet monitored for other purposes (national PRTR, licences or MEA commitments) in a *given country (n)* in a given *time period (t)*
$\underset{(u\times n)}{A11C_t} \quad t=\{0,1\}$	$A11C_t[u,n]=A10_t[u,n] * A71C[u,n]$	Same concept as matrix A11E with the difference that this matrix uses the capacity threshold approach
$\underset{((m+c+e)\times n)}{A12E_t} \quad t=\{0,1\}$	$= A8_t \cdot A11E_t$	Number of hours in a given *country (n)* that will be needed by all facilities for a given *measurement (m)*, *calculation (c)* or *estimation action (e)* using the employee threshold approach in a given *time period (t)*
$\underset{((m+c+e)\times n)}{A12C_t} \quad t=\{0,1\}$	$= A8_t \cdot A11C_t$	Same concept as matrix A12E with the difference that this matrix uses the capacity threshold approach
$\underset{((m+c+e)\times n)}{A13E_t} \quad t=\{0,1\}$	$A13E_t[i,n]=A12E_t[i,n] * I_t[i,n]$ $\mathrm{i}=\{1,\ldots,(\mathrm{m}+\mathrm{c}+\mathrm{e})\}$	EMHs required for a given *measurement (m)*, *calculation (e)* or *estimation action (e)* in a given *country (n)* using the employee threshold approach in a given *time period (t)*
$\underset{(1\times n)}{ha_t} \quad t=\{0,1\}$	$ha_t[n]=\sum_{i=1}^{m+c+e} A13E_t[i,n]$ $i=\{1,\ldots,(m+c+e)\}$	Total EMHs required in a given *country (n)* in a given *time period (t)* using the employee threshold approach

$\underset{((m+c+e)\times n)}{A13C_t}$ $t=\{0,1\}$	$A13C_t[i,n]=A12C_t[i,n]*I_t[i,n]$ $\mathrm{i}=\{1,\ldots,(\mathrm{m}+\mathrm{c}+\mathrm{e})\}$	Same concept as matrix A13E with the difference that this matrix uses the capacity threshold approach
$\underset{(1\times n)}{ia_t}$ $t=\{0,1\}$	$ia_t[n]=\sum_{i=1}^{m+c+e}A13C_t[i,n]$ $i=\{1,\ldots,(m+c+e)\}$	Same concept as vector *ha* with the difference that this vector uses the capacity threshold approach
$\underset{(n\times 1)}{w}$	Input	Total number of facilities performing initial actions in a given *country (n)*. NB this applies only to the first reporting period (t=0)
$\underset{(n\times 1)}{x_t}$ $t=\{0,1\}$	$x_0=f(w)$ or input $x_1=f(w)$ or $f(x_0)$ or input	Total number of reporting facilities in a given *country (n)* in a given *time period (t)*. NB this is equal to the total number of reports in a given *country (n)* in a given *time period (t)*
$\underset{(n\times v)}{Y}$	Input	Total number of facilities performing initial actions in a given *country (n)* and given *activity (v)*. NB this applies only to the first reporting period (t=0)
$\underset{(n\times v)}{Z_t}$ $t=\{0,1\}$	$Z_0=f(Y)$ or input $Z_1=f(Y)$ or $f(Z_0)$ or input	Number of facilities in a *given country (n)* and in a given *activity (v)* and in a given *time period (t)*
$\underset{(u\times 1)}{m1}$	Input	A '1' is assigned if a given *substance (u)* <u>is</u> required to be monitored by the Aarhus ACP and concerns emission releases to air, using the employee threshold regime; <u>otherwise</u>, a '0' is assigned
$\underset{(u\times 1)}{m2}$	Input	Same concept as vector $m1$, but using the capacity threshold regime
$\underset{(u\times 1)}{m3}$	Input	Same concept as vector $m1$, but relates to emission releases to water
$\underset{(u\times 1)}{m4}$	Input	Same concept as vector $m3$, but using the capacity threshold regime
$\underset{(u\times 1)}{m5}$	Input	Same concept as vector $m1$, but relates to emission releases to land
$\underset{(u\times 1)}{m6}$	Input	Same concept as vector $m5$, but using the capacity threshold regime
$\underset{(u\times 1)}{m7}$	Input	Same concept as vector $m1$, but relates to transfers of water waste

		{relevant?}
$\underset{(u\times 1)}{m8}$	Input	Same concept as vector $m7$, but using the capacity threshold regime
$\underset{(u\times 1)}{m9}$	Input	Same concept as vector $m1$, but relates to transfers of waste under the pollutant specific regime {does this exist under employee threshold approach?}
$\underset{(u\times 1)}{m10}$	Input	Same concept as vector $m9$, but using the capacity threshold regime
$\underset{(u\times 1)}{m11}$	Input	Same concept as vector $m1$, but relates to transfers of hazardous waste under the waste-specific regime {does this exist under employee threshold approach?}
$\underset{(u\times 1)}{m12}$	Input	Same concept as vector $m11$, but using the capacity threshold regime
$\underset{(u\times 1)}{m13}$	Input	Same concept as vector $m1$, but relates to transfers of non-hazardous waste under the waste-specific regime {does this exist under the employee threshold approach?}
$\underset{(u\times 1)}{m14}$	Input	Same concept as vector $m13$, but using the capacity threshold regime
$\underset{(n\times 1)}{r1_t}$ $t=\{0,1\}$	If decentralised regulator: $r1_t[n]=1$; Otherwise: $r1_t[n]=0$ (Input)	Indicates whether coordination costs included (i.e. in the case of a decentralised regulatory structure) in a given *country (n)*
$\underset{(n\times 1)}{r2_t}$ $t=\{0,1\}$	Input	Percentage of additional engineers' working hours needed to coordinate the decentralized operations in a given *country (n)*
$\underset{(n\times 1)}{r3_t}$ $t=\{0,1\}$	Input	Same concept as vector r2 with the difference that this vector monitors the required additional working time by the administrator
$\underset{(n\times 1)}{r4_t}$ $t=\{0,1\}$	Input	Number of fixed hours of engineer required to undertake tasks if regulator has centralized operations in a given *country (n)*
$\underset{(n\times 1)}{r5_t}$ $t=\{0,1\}$	$r5_t[n]=r4_t[n]*(1+r1_t[n]*r2_t[n])$	Number of fixed hours engineer required to undertake tasks regardless of whether regulator is centralised or not in a given *country (n)*.
$\underset{(n\times 1)}{r6_t}$ $t=\{0,1\}$	Input	Same concept as vector r4 with the difference that this vector applies to the administrator's time

$\underset{(n\times 1)}{r7_t} \quad t=\{0,1\}$	$r7_t[n]=r6_t[n]*(1+r1_t[n]*r3_t[n])$	Same concept as vector r5 with the difference that this vector applies to the administrator’s time
$\underset{(n\times 1)}{r8_t} \quad t=\{0,1\}$	Input	Hours of engineers’ time required per report to process the PRTR data in a given *country (n)*
$\underset{(n\times 1)}{r9_t} \quad t=\{0,1\}$	Input	Same concept as vector r8 with the difference that this vector applies to the administrator’s time
$\underset{(n\times 1)}{r10_t} \quad t=\{0,1\}$	$r10_t[n]=r8_t[n]*\frac{gtotal_t[n]}{x_t[n]}$	Total number of variable hours required by the engineer in a given *country (n)*
$\underset{(n\times 1)}{r11_t} \quad t=\{0,1\}$	$r11_t[n]=r9_t[n]*\frac{gtotal_t[n]}{x_t[n]}$	Same concept as vector r10 with the difference that this vector applies to the administrator’s time
$\underset{(n\times 1)}{r12_t} \quad t=\{0,1\}$	$=r5_t+r10_t$	Total hours of engineer’s time required in a given *country (n)*
$\underset{(n\times 1)}{r13_t} \quad t=\{0,1\}$	$=r7_t+r11_t$	Same concept as vector r12 with the difference that this vector applies to the administrator’s time
$\underset{(n\times 1)}{r14_t} \quad t=\{0,1\}$	Input	Number of annual working hours of an engineer in a given *country (n)*
$\underset{(n\times 1)}{r15_t} \quad t=\{0,1\}$	Input	Same concept as vector r14 with the difference that this vector applies to the number of annual working hours of an administrator
$\underset{(n\times 1)}{r16_t} \quad t=\{0,1\}$	$r16_t[n]=\frac{r12_t[n]}{r14_t[n]}$	Number of required engineers in a given *country (n)*
$\underset{(n\times 1)}{r17_t} \quad t=\{0,1\}$	$r17_t[n]=\frac{r13_t[n]}{r15_t[n]}$	Same concept as vector r16 with the difference that this vector applies to number of required administrators
$\underset{(n\times 1)}{r18_t} \quad t=\{0,1\}$	Input	Employee benefits (as % of gross salary) in a given *country (n)*
$\underset{(n\times 1)}{r19_t} \quad t=\{0,1\}$	Input	OH costs for engineer (as % of gross salary) in a given *country (n)*
$\underset{(n\times 1)}{r20_t} \quad t=\{0,1\}$	Input	Same concept as vector r19 with the difference that this vector applies to the administrator’s OH costs

$\underset{(n\times 1)}{r21_t} \quad t=\{0,1\}$	Input	Gross annual salary of an engineer working for the regulator in a given *country (n)*
$\underset{(n\times 1)}{r22_t} \quad t=\{0,1\}$	Input	Same concept as vector r21 with the difference that this vector applies to the administrator's gross annual salary
$\underset{(n\times 1)}{r23_t} \quad t=\{0,1\}$	Input	Income tax rate per regulator employee in a given *country (n)*. {needed only if we calculate the loaded salary using the net salary}
$\underset{(n\times 1)}{r24_t} \quad t=\{0,1\}$	$r24_t[n]=r21_t[n]*(1+r18_t[n]+r19_t[n])$	Loaded salary per engineer in a given *country (n)* {if we use net salary, r24 has to be adjusted to consider that}
$\underset{(n\times 1)}{r25_t} \quad t=\{0,1\}$	$r25_t[n]=r22_t[n]*(1+r18_t[n]+r20_t[n])$	Same concept as vector r24 with the difference that this vector applies to the administrator's salary {if we use net salary, r25 has to be adjusted to consider that}
$\underset{(n\times 1)}{r26_t} \quad t=\{0,1\}$	$r26_t[n]=r24_t[n]*r16_t[n]$	Total loaded salary bill for engineers (i.e. labour cost for engineers) in a given *country (n)*
$\underset{(n\times 1)}{r27_t} \quad t=\{0,1\}$	$r27_t[n]=r25_t[n]*r17_t[n]$	Same concept as vector r26 with the difference that this vector applies to the administrator's salary
$\underset{(n\times 1)}{r28_t} \quad t=\{0,1\}$	$=r26_t+r27_t$	Total loaded salary (i.e. labour cost) in a given *country (n)*
$\underset{(n\times 1)}{r29_t} \quad t=\{0,1\}$	Input	Fixed IT cost in a given *country (n)*
$\underset{(n\times 1)}{r30_t} \quad t=\{0,1\}$	Input	Variable IT cost per number of pollutants reported in a given *country (n)*
$\underset{(n\times 1)}{r31_t} \quad t=\{0,1\}$	$r31_t[n]=r30_t[n]*gtotal_t[n]$	Total variable IT cost in a given *country (n)*
$\underset{(n\times 1)}{r32_t} \quad t=\{0,1\}$	$=r29_t+r31_t$	Total IT cost in a given *country (n)*
$\underset{(n\times 1)}{r33_t} \quad t=\{0,1\}$	$=r28_t+r32_t$	Total cost to regulator in a given *country (n)*
$\underset{(n\times 1)}{ts_t} \quad t=\{0,1\}$	$=s_t+r33_t$	Total national cost in a given *country (n)* in a given *time period (t)* using the employee threshold approach
$\underset{(n\times 1)}{tt_t} \quad t=\{0,1\}$	$=t_t+r33_t$	Total national cost in a given *country (n)* in a given *time period (t)* using the capacity threshold approach

Notes:
t=time period {0,1}
n=country {1,…,56}
s=facility staff type {1,…,4}
p=general initial action {1,…,5}
q=general final action {1,…,3}
z=(p+q)*s
m=measurement action {1,…,30}
c=calculation action {1,…,30}
e=estimation action {1,…,30}
y=(m+c+e)*s
u=substance {1,…,86}
v=activity {1,…,67}
ℓ=MEA {1,…,11}
o=national PRTR {1,…,6}