Annex 4: Energy Labelling Air Conditioner Equations and Calculations

1 Guidance on the Calculations and Production of Equations from within EU Regulation 626/2011 Energy Labelling of Air Conditioners

1.1 Introduction

This document was produced to support the adoption by the Council of Ministers and the subsequent implementation in Ukraine of the draft Technical Regulation for the Energy Labelling of Air Conditioners. The document has three objectives:

1. To make suggestions for separating out from the text based definitions used in Annex I of 626/2011 the equations that are contained therein, and distil these equations into their typical – non-text based – format. The outcome of this objective will seek to satisfy the requirements within the Resolution of the Cabinet of Ministers of Ukraine #708 dated 18 June 2012 which requires that for Technical Regulations in Ukraine, normative references be excluded from definitions. Currently within Annex I, Definitions, of Commission Regulation 626/2011 this is not the case. Without rectifying this situation, the draft Technical Regulation for Air Conditioners cannot be approved by the Council of Ministers in Ukraine.
2. To provide guidance on how calculations necessary for the production of air conditioner energy label parameters are calculated. The outcome of this objective will aid the understanding of the reviewing authorities of the draft Technical Regulation and satisfy the related concerns expressed within the Expert Opinion from the Council of Ministers.
3. To present the excerpt from Annex I of Commission Regulation 842/2006 regarding the global warming potential of certain fluorinated greenhouse gases. This shall be featured in full in a revised Annex VII of the draft Technical Regulation for Energy Labelling of Air Conditioners in Ukraine in order to satisfy the Expert Opinion from the Council of Ministers.

1.1.1 Product Scope – Single and Double Duct Air Conditioners

Table 1.1 displays an image of the type of air-conditioner considered under this section; a single duct air conditioner. Double duct air conditioners are considered to be rare within the EU. A double duct air conditioner is comprised of a single package indoor unit with ducts for condenser air outlet and inlet.

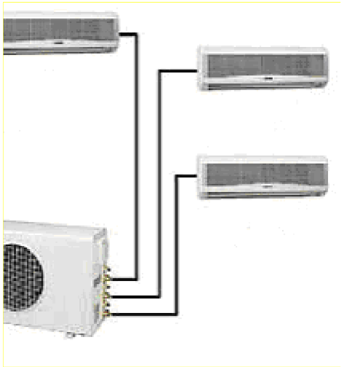
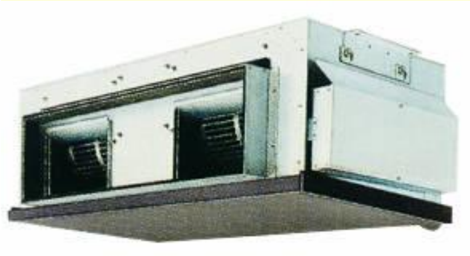
Table 1.1 Image of a Single Duct Room Air Conditioner

Single duct, integrated indoor unit with (flexible) condenser air outlet duct

1.1.2 Product Scope – Split and Multi-split Air Conditioners

Table 1.2 displays a group of images covering the array of split and multi-split air conditioners, together with a description against each image.

Table 1.2 Images of various Split and Multi-split formatted Air Conditioners

	
Split-unit with fixed outdoor and indoor unit; not ducted	Split-unit with fixed outdoor and mobile indoor unit; not ducted
	
Multi-split with fixed separate indoor units; not ducted	Multi-split; ducted

1.2 Definitions for Change in Annex I 626/2011 & Distilled Equations

In line with objective 1, Table 1.3 below presents the definitions identified for change from Annex I 626/2011 and the resulting equations.

Table 1.3 Definitions for Change and Resulting Equations from Annex I 626/2011

Current Location in EU 626/2001	Text	Proposed Change for Inclusion in Annex VII	Where
Annex I (5)	'*Rated energy efficiency ratio*' (*EER rated*) means the *declared capacity* for cooling [kW] divided by the *rated power input for cooling* [kW] of a unit when providing cooling at *standard rating conditions*;	$EERrated = \frac{Rated\ Power\ Output\ Cooling\ Capacity\ (kW)}{Rated\ Power\ Input\ for\ Cooling\ (kW)}$	EERrated is also referred to as declared Energy Efficiency Ratio [EERd(Tj)]
Annex I (7)	'*Global warming potential*' (*GWP*) means the measure of how much 1 kg of the refrigerant applied in the vapour compression cycle is estimated to contribute to global warming, expressed in kg CO_2 equivalents over a 100 year time horizon;	$GWP\ of\ 1kg\ X\ = Y\ kgCO2e$	GWP = Global Warming Potential X = Refrigerant used in the Air Conditioner Y = The refrigerant's GWP value from the table in Annex I, 842/2006.
Annex I (7)	GWP values considered will be those set out in Annex I of Regulation (EC) No 842/2006 of the European Parliament and of the Council	See section 1.4 below	N/A
Annex I (15)	'Part load ratio' (*pl(Tj)*) means the *outdoor temperature minus* 16°C, divided by the *reference design temperature* minus 16°C, for either cooling or heating;	$Part\ load\ ratio\ (pl(Tj)) = \frac{(Outdoor\ temperature - 16C)}{(Reference\ design\ temperature - 16C)}$	N/A
Annex I (19)	'*Seasonal energy efficiency ratio*' (*SEER*) is the overall energy efficiency ratio of the unit, representative for the whole cooling season, calculated as the *reference annual cooling demand* divided by the *annual electricity consumption for cooling*;	$SEER = \frac{QC}{QCE}$	QC = Reference Annual Cooling Energy Demand QCE = Annual Electricity Consumption for Cooling
		$SEER = \frac{Reference\ Annual\ Cooling\ Energy\ Demand\ (kWh/a)}{Annual\ Electricity\ Consumption\ for\ Cooling (kWh/a)}$	N/A
Annex I (20)	'*Reference annual cooling demand*' (*QC*) means the reference cooling demand [kWh/a] to be used as basis for calculation of	$\mathrm{QC = Pdesignc \times HCE}$ *(Measured in kWh/a)*	Pdesignc = Design cooling load, which means the cooling load applied to the unit at reference design conditions,

	SEER and calculated as the product of the *design load for cooling* (*Pdesignc*) and the *equivalent active mode hours* for cooling (*HCE*);		whereby the design cooling load is equal to rated cooling power output capacity at outdoor temperature (Tj) equal to reference design temperature for cooling (Tdesignc), expressed in kW HCE = Equivalent Active Mode Hours for Cooling
Annex I (22)	'*Annual electricity consumption for cooling*' (*QCE*) means the electricity consumption [kWh/a] required to meet the *reference annual cooling* demand and is calculated as the *reference annual cooling demand* divided by the *active mode seasonal energy efficiency ratio* (*SEERon*), and the electricity consumption of the unit for *thermostat off-, standby-, off- and crankcase heater-mode* during the cooling season;	$QCE = \frac{QC}{SEERon} + (\mathrm{Hto} \times \mathrm{Pto}) + (\mathrm{Hsb} \times \mathrm{Psb}) + (\mathrm{Hck} \times \mathrm{Pck}) + (\mathrm{Hoff} \times \mathrm{Poff})$ *(Measured in kWh/a)*	SEERon = Active mode Seasonal Energy Efficiency Ratio Hto = Thermostat OFF mode operating hours Pto = Thermostat OFF mode power consumption Hsb = Standby mode operating hours Psb = Standby mode power consumption Hck = Crankcase heating mode operating hours Pck = Crankcase heating mode power consumption Hoff = Off mode operating hours Poff = Off mode power consumption
Annex I (23)	'*Active seasonal mode energy efficiency ratio*' (*SEERon*) means the average energy efficiency ratio of the unit in active mode for the cooling function, constructed from *part load* and *bin-specific energy efficiency ratio's* (EERbin(Tj)) and weighted by the *bin hours* the *bin* condition occurs;	$SEERon = \frac{\sum_{j=i}^{n} hj \times Pc\,(Tj)}{\sum_{j=i}^{n} hj \times (\frac{Pc\,(Tj)}{EERbin\,(Tj)})}$	hj = bin hours Pc (Tj) = Part load for cooling EERbin (Tj) = bin specific Energy Efficiency Ratio
Annex I (24)	'*Part load*' means the cooling load (*Pc(Tj)*) or the heating load (*Ph(Tj)*) [kW] at a specific outdoor temperature *Tj*, calculated as the design load multiplied by the *part load ratio*;	$Pc(Tj) = \mathrm{Pdesignc} \times pl(Tj)$ *(Measured in kW)*	Pdesignc = Design load for cooling pl(Tj) = Part load ratio
		$Ph(Tj) = \mathrm{Pdesignh} \times pl(Tj)$	Pdesignh = Design load for heating

		(Measured in kW)	pl(Tj) = Part load ratio
Annex I (25)	‘*Bin-specific energy efficiency ratio*’ (*EERbin(Tj)*) means the energy efficiency ratio specific for every *bin* j with *outdoor temperature* Tj in a season, derived from the *part load*, *declared capacity* and *declared energy efficiency ratio* (*EERd(Tj)*) for specified *bins* (j) and calculated for other *bin*s through inter/extrapolation, when necessary corrected by the *degradation coefficient*; ‘Bin hours’ (hj) means the hours per season, expressed in hours per year, at which an outdoor temperature occurs for each bin, as set out in Table 1.4 and Table 1.5	$$EERbin(Tj) = EERd(Tj) \times \left(\frac{CRu}{Cdc \ \times CRu + (1 - Cc)}\right)$$	EERd(Tj) = Declared Energy Efficiency Ratio CRu = Capacity ratio Cdc = Degradation coefficient (cooling), which means the measure of efficiency loss due to cycling of the product; if it is not determined by measurement then the default degradation coefficient shall be 0.25 for an air conditioner or heat pump.
	‘Capacity ratio’ (CRu) means the part load for cooling Pc(Tj) divided by the declared cooling capacity Pdc(Tj);	$$CRu = \frac{Pc\ (Tj)}{Pdc\ (Tj)}$$	Pc (Tj) = Part load for cooling Pdc (Tj) = Declared cooling output capacity
Annex I (6)	‘*Rated coefficient of performance*’ (*COPrated*) means the rated power output capacity for heating [kW] divided by the *rated power input for heating* [kW] of a unit when providing heating at *standard rating conditions*;	$$COPrated = \frac{Rated\ Power\ Output\ Heating\ Capacity\ (kW)}{Rated\ Power\ Input\ for\ Heating\ (kW)}$$	COPrated is also referred to as declared Coefficient of Performance [COPd(Tj)]
Annex I (26)	‘*Seasonal coefficient of performance*’ (*SCOP*) is the overall coefficient of performance of the unit, representative for the whole designated heating season (the value of SCOP pertains to a designated heating season), calculated as the *reference annual heating demand* divided by the *annual electricity consumption for heating*;	$$SCOP = \frac{QH}{QHE}$$	QH = Reference Annual Heating Energy Demand QHE = Annual Electricity Consumption for Heating
		$$SCOP = \frac{Reference\ Annual\ Heating\ Energy\ Demand\ (kWh/a)}{Annual\ Electricity\ Consumption\ for\ Heating\ (kWh/a)}$$	N/A
Annex I (27)	‘*Reference annual heating demand*’ (*QH*) means the reference heating demand [kWh/a], pertaining to a designated *heating season*, to be used as basis for calculation of	$$\mathrm{QH} = \mathrm{Pdesignh} \times \mathrm{H\ HE}$$ *(Measured in kWh/a)*	Pdesignh = Design load for heating H_{HE} = Equivalent active mode hours for heating

	SCOP and calculated as the product of the *design load for heating* (*Pdesignh*) and the *seasonal equivalent active mode hours for heating* (H_{HE});		
Annex I (29)	'*Annual electricity consumption for heating*' (Q_{HE}) means the electricity consumption [kWh/a] required to meet the indicated *reference annual heating demand* and which pertains to a designated heating season; and is calculated as the *reference annual heating demand* divided by the *active mode seasonal coefficient of performance* (*SCOP*on), and the electricity consumption of the unit for *thermostat off-, standby-, off- and crankcase heater-mode* during the heating season;	$QHE = \frac{QH}{SCOPon} + (\mathrm{Hto} \times \mathrm{Pto}) + (\mathrm{Hsb} \times \mathrm{Psb}) + (\mathrm{Hck} \times \mathrm{Pck}) + (\mathrm{Hoff} \times \mathrm{Poff})$ *(Measured in kWh/a)*	SCOPon = Active mode Seasonal Coefficient of Performance Hto = Thermostat OFF mode operating hours Pto = Thermostat OFF mode power consumption Hsb = Standby mode operating hours Psb = Standby mode power consumption Hck = Crankcase heating mode operating hours Pck = Crankcase heating mode power consumption Hoff = Off mode operating hours Poff = Off mode power consumption
Annex I (30)	'*Active mode seasonal coefficient of performance*' (*SCOP*on) means the average coefficient of performance of the unit in active mode for the designated heating season, constructed from the *part load, electric back up heating capacity* (where required) and *bin-specific coefficients of performance* (*COPbin(Tj)*) and weighted by the bin hours the bin condition occurs;	$SCOPon = \frac{\sum_{j=i}^{n} hj \times Ph\,(Tj)}{\sum_{j=i}^{n} hj \times \left(\frac{Ph\,(Tj) - elbu\,(Tj)}{COPbin\,(Tj)}\right) + elbu(Tj)}$	hj = bin hours Ph (Tj) = Part load for heating COPbin (Tj) = bin specific Coefficient of Performance Elbu(Tj) = Electric backup heating capacity
Annex I (32)	'*Bin-specific coefficient of performance*' (*COPbin(Tj)*) means the coefficient of performance specific for every *bin j with outdoor temperature* Tj in a season, derived from the *part load, declared capacity* and *declared coefficient of performance* (*COPd(Tj)*) for specified *bins* (*j*) and	$COPbin(Tj) = COPd(Tj) \times (1 - Cdh \times (1 - CRu))$	COPd(Tj) = Declared Coefficient of Performance CRu = Capacity ratio Cdh = Degradation coefficient (heating)

	calculated for other *bins* through inter/extrapolation, when necessary corrected by the *degradation coefficient*;		

Table 1.4 European heating seasons for heat pumps (extracted from Lot21 WD)

bin_j	T_j [°C]	H_j [h/annum]		
		Warmer	Average	Colder
1 to 8	-30 to -23	0	0	0
9	-22	0	0	1
10	-21	0	0	6
11	-20	0	0	13
12	-19	0	0	17
13	-18	0	0	19
14	-17	0	0	26
15	-16	0	0	39
16	-15	0	0	41
17	-14	0	0	35
18	-13	0	0	52
19	-12	0	0	37
20	-11	0	0	41
21	-10	0	1	43
22	-9	0	25	54
23	-8	0	23	90
24	-7	0	24	125
25	-6	0	27	169
26	-5	0	68	195
27	-4	0	91	278
28	-3	0	89	306
29	-2	0	165	454
30	-1	0	173	385
31	0	0	240	490
32	1	0	280	533
33	2	3	320	380
34	3	22	357	228
35	4	63	356	261
36	5	63	303	279
37	6	175	330	229
38	7	162	326	269
39	8	259	348	233
40	9	360	335	230
41	10	428	315	243
42	11	430	215	191
43	12	503	169	146
44	13	444	151	150
45	14	384	105	97
46	15	294	74	61
Total hours:		3 590	4 910	6 446

Table 1.5 European cooling season for air conditioners (extracted from Lot21 WD)

Bins	Outdoor temperature (dry bulb)	"Average cooling season"	EER calculation
		bin hours	
j	T_j	h_j	
#	°C	h/annum	
1	17	205	EER(D)
2	18	227	EER(D)
3	19	225	EER(D)
4	20	225	D - Measured value

5	21	216	Linear interpolation
6	22	215	Linear interpolation
7	23	218	Linear interpolation
8	24	197	Linear interpolation
9	25	178	C - Measured value
10	26	158	Linear interpolation
11	27	137	Linear interpolation
12	28	109	Linear interpolation
13	29	88	Linear interpolation
14	30	63	B - Measured value
15	31	39	Linear interpolation
16	32	31	Linear interpolation
17	33	24	Linear interpolation
18	34	17	Linear interpolation
19	35	13	A - Measured value
20	36	9	EER(A)
21	37	4	EER(A)
22	38	3	EER(A)
23	39	1	EER(A)
24	40	0	EER(A)

1.3 Calculating the Energy Efficiency Class for an Air Conditioner under Commission Regulation 626/2011

Table 1.6 presents a worked example of how the cooling and heating performance is calculated for Single and Double Duct Air Conditioners.

Table 1.6 Example Calculation for a Single and Double Duct Air Conditioner – Heating and Cooling

Air conditioners are assigned an energy efficiency class on the basis of their rated Energy Efficiency Ratio (EER_{rated}) for cooling and rated Coefficient of Performance (COP_{rated}) for heating.

$$EERrated = \frac{Declared\ Capacity\ for\ Cooling\ (kW)}{Rated\ Power\ Input\ for\ Cooling\ (kW)}$$

$$COPrated = \frac{Declared\ Capacity\ for\ Heating\ (kW)}{Rated\ Power\ Input\ for\ Heating\ (kW)}$$

Therefore, a single duct air conditioner with a cooling capacity of 3.38 kW and a power input of 1.05 kW would achieve an EER_{rated} of 3.2. Comparing that with the look-up table opposite gives an A+ rating.

The same air conditioner, with a heating capacity of 3.91 kW and a power input of 1.19kW would achieve a COP_{rated} of 3.3. Comparing that with the look-up table opposite gives an A++ rating.

Energy efficiency classes for double ducts and single ducts

Energy Efficiency Class	Double ducts		Single ducts	
	EER_{rated}	COP_{rated}	EER_{rated}	COP_{rated}
A+++	≥ 4,10	≥ 4,60	≥ 4,10	≥ 3,60
A++	3,60 ≤ EER < 4,10	4,10 ≤ COP < 4,60	3,60 ≤ EER < 4,10	3,10 ≤ COP < 3,60
A+	3,10 ≤ EER < 3,60	3,60 ≤ COP < 4,10	3,10 ≤ EER < 3,60	2,60 ≤ COP < 3,10
A	2,60 ≤ EER < 3,10	3,10 ≤ COP < 3,60	2,60 ≤ EER < 3,10	2,30 ≤ COP < 2,60
B	2,40 ≤ EER < 2,60	2,60 ≤ COP < 3,10	2,40 ≤ EER < 2,60	2,00 ≤ COP < 2,30
C	2,10 ≤ EER < 2,40	2,40 ≤ COP < 2,60	2,10 ≤ EER < 2,40	1,80 ≤ COP < 2,00
D	1,80 ≤ EER < 2,10	2,00 ≤ COP < 2,40	1,80 ≤ EER < 2,10	1,60 ≤ COP < 1,80
E	1,60 ≤ EER < 1,80	1,80 ≤ COP < 2,00	1,60 ≤ EER < 1,80	1,40 ≤ COP < 1,60
F	1,40 ≤ EER < 1,60	1,60 ≤ COP < 1,80	1,40 ≤ EER < 1,60	1,20 ≤ COP < 1,40
G	< 1,40	< 1,60	< 1,40	< 1,20

1.4 Extract from Annex I 842/2006 for inclusion in Annex VII

Part 1 **Fluorinated Greenhouse Gases**

Fluorinated Greenhouse Gas	Chemical Formula	Global Warming Potential (GWP)
Sulphur hexafluoride	SF_6	22,200
Hydrofluorocarbons (HFCs):		
HFC-23	CHF_3	12,000
HFC-32	CH_2F_2	550
HFC-41	CH_3F	97
HFC-43-10mee	$C_5H_2F_{10}$	1,500
HFC-125	C_2HF_5	3,400
HFC-134	$C_2H_2F_4$	1,100
HFC-134a	CH_2FCF_3	1,300
HFC-152a	$C_2H_4F_2$	120
HFC-143	$C_2H_3F_3$	330
HFC-143a	$C_2H_3F_3$	4,300
HFC-227ea	C_3HF_7	3,500
HFC-236cb	$CH_2FCF_2CF_3$	1,300
HFC-236ea	CHF_2CHFCF_3	1,200
HFC-236fa	$C_3H_2F_6$	9,400
HFC-245ca	$C_3H_3F_5$	640
HFC-245fa	$CHF_2CH_2CF_3$	950
HFC-365mfc	$CF_3CH_2CF_2CH_3$	890
Perfluorocarbons (PFCs):		
Perfluoromethane	CF_4	5,700
Perfluoroethane	C_2F_6	11,900
Perfluoropropane	C_3F_8	8,600
Perfluorobutane	C_4F_{10}	8,600
Perfluoropentane	C_5F_{12}	8,900

Perfluorohexane	C_6F_{14}	9,000
Perfluorocyclobutane	$c\text{-}C_4F_8$	10,000

Part 2

Method of calculating the total global warming potential (GWP) for a preparation

The total GWP for a preparation is a weighted average, derived from the sum of the weight fractions of the individual substances multiplied by their GWPs.

Σ (Substance X % x GWP) + (Substance Y % x GWP) + … (Substance N % x GWP)

where % is the contribution by weight with a weight tolerance of +/- 1 %.

For example: applying the formula to a theoretical blend of gases consisting of 23 % HFC-32; 25 % HFC-125 and 52 % HFC-134a;

Σ (23 % x 550) + (25 % x 3 400) + (52 % x 1 300)

→ Total GWP = 1,652,5