Stakeholder consultation
Ecodesign Requirements for DG ENTR Lot 1 Professional Refrigeration:
High temperature industrial process Chillers

ANNEX 3: Summary of supporting evidence

1. Introduction

The general case for ecodesign regulation of industrial process chillers of low, medium and high temperature was thoroughly examined in the impact assessment study carried out during January to September 2012 and available at http://www.taitconsulting.co.uk/Ecodesign_Consultation.html. At that time, insufficient evidence was available to facilitate the setting of thresholds for minimum requirements for high temperature chillers. However, this Annex provides a summary of evidence regarding energy efficiency performance of high-temperature industrial process chillers that was gathered between December 2012 and February 2013 (with the assistance of CLASP Europe). This evidence was used as the basis to derive proposed minimum performance requirement thresholds and other aspects of the proposed regulation.

See also the following documents:

- Consultation questionnaire on high temperature industrial process chillers (Word document or identical PDF version)
- Annex 1: Transitional Method For Determination Of The SEPR (Seasonal Energy Performance Ratio) For Chillers Used For Refrigeration And Industrial Applications, Draft of 20 December 2012 (PDF document)
- Annex 2: SEPR calculation spreadsheet tool for Process chillers (Excel spreadsheet, Version 1.5 dated 7 January 2013)
- Annex 3: Summary of supporting evidence (background on product data analysis and justification for thresholds, PDF document) (*this document)*

The latest versions of these documents and more information can be found at: http://www.taitconsulting.co.uk/Ecodesign_Consultation.html

2. Data collection

In order to establish current market average and best energy efficiency performance levels available on the market in terms of SEPR, the most robust approach would be to obtain a wide range of real product data and use that to calculate SEPR according to the proposed SEPR methodology. In December 2012 manufacturers of process chillers were invited by the Commission to submit product performance data using a standard data submission template via the Eurovent chiller group and the Joint Industry Expert Group (under EPEE).

3. Assessment of available data against the wider market

Data on 53 different chillers (22 air cooled; 31 water cooled) was received from 8 different manufacturers. The submitted data was judged to provide a fairly good representation of the market in terms of currently common compressor technologies and controls, refrigerant fluids (see Table 5) and heat exchanger types. The data submitted by manufacturers enabled calculation of SEPR for all but 5 of those chillers.

It was recognised that the process chiller product sample may not fully reflect products with below average performance and nor does it include all sub-types of chiller. In order to give additional context and indicate how it might compare with the full market, it was decided to make comparisons with the much larger Eurovent certification dataset[1]:

i. The EER and ESEER values for the submitted process chillers were compared with the values and market averages published by Eurovent (as used as the basis for the Lot 6 minimum requirements analysis). This showed that the process chiller sample covers a significant proportion of the capacity range and EER range, and also much of the ESEER range (with some exceptions) – see Figure 1 and Figure 2. However, coverage is thin at low and high capacity extremes.

ii. The process chiller performance data submitted by manufacturers enabled the generation of indicators for the ratio between EER and SEPR – carried out with careful consideration of how the different technologies affect this ratio[2] and how it varies across capacity ranges. Using these ratios, indicative median[3] and high performance SEPR estimates for the Eurovent dataset were derived to compare with those calculated from the process chillers (see Table 6 and Table 7 for details of figures derived for the Eurovent data set). EER and ESEER figures were also compared between the two data sets – see Table 1 and Table 2. These tables show that the median Eurovent EER, ESEER and SEPR performance levels compare fairly closely with the averages of the submitted industrial chiller data set (within 6% on air cooled and 7% for water cooled) – except for the 15% higher SEPR figures achieved in the industrial chiller data set for larger water cooled chillers.

The cross check of submitted data across available process chiller technologies and the comparison with Eurovent performance data builds confidence that the dataset is broadly representative of available technologies and performance ranges, but with an understood skew towards better performing products in larger water cooled chillers.

4. Benchmark levels – best performance

Next, indicators were derived for the best available technologies by SEPR for use as 'benchmark' levels. This is taken to indicate a medium-term best available technology (available

[1] Comparisons with Eurovent data must also be made with caution: it is focused predominantly on chillers for air conditioning and whilst it covers 90% of all EU chiller sales, there are important industrial process chillers technologies that will not be represented in the Eurovent dataset - for example ammonia chillers and large capacity chillers.

[2] It was established that these ratios would be different for each technology type and so overall conversion between EER or ESEER and SEPR would not be reliable.

3 Median performance was used instead of mean to reduce the influence of outliers and peculiar technology combinations.

on, or close to, the market but not yet fully exploited). This was done by examining the best EER in the Eurovent certification dataset and applying the indicative ratios for SEPR/EER described above. The benchmark SEPR values derived were also assessed for feasibility against known technologies and improvement potentials, seeking performance levels that could be achieved by products currently available from a small number of manufacturers. These are shown in Table 3. It is anticipated that the market average performance should be able to match these figures in around 10 years' time.

5. Product definition

The product definition as previously used in the working documents from 2012 for industrial process chillers is carried over for use in this consultation. Further to this, it is necessary to distinguish between high-temperature chillers used for air conditioning applications, and high-temperature chillers used for industrial process applications because air conditioning chillers may be covered by planned eco-design regulation under DG ENER Lot 6 (see http://ecohvac.eu/index.html; the impact assessment study for that regulation is ongoing at February 2013). Separate and different minimum requirements are appropriate, as explained in the section '*The case for ambitious minimum requirements'* below. The primary means to distinguish between these two types identified so far is:

> *High-temperature industrial process chillers meet the above definition and are chillers designed to operate the whole year round, including in ambient temperatures below [10°C - exact temperature to be confirmed]. Note that having the functionality for free cooling operation does not on its own qualify a chiller as being "designed for year-round operation".*

Further consideration will be required to ensure that the definitions for high-temperature industrial process chillers and for air conditioning chillers are complementary and adequately robust for the purposes of clarity for manufacturers and for market surveillance and compliance activities. Development of the definition for chillers under Lot 6 is ongoing at February 2013. The Lot 6 definition and comments received as a result of this consultation will be taken into account by the Commission in due course.

6. Capacity segments

Consideration was next given to the necessary capacity segments into which the market should be divided. Note that the segmentation for publishing benchmark levels (aspirational / high performance) is slightly different to the proposed segmentation for minimum requirements:

- For air cooled chillers it is proposed not to have a separate segment below 100 kW at all. This separation was proposed for air-conditioning chillers under Lot 6 in order to make allowance for poorer performing scroll HFC chillers that dominate for small air conditioning chillers. However, for industrial chillers SEPR values for on-off units are comparable with those of chillers with several capacity steps from 0 to well above 100 kW; furthermore, in future double stage VFD rotary compressors should be encouraged due to their better full and part load performance. Hence it is not appropriate to 'protect' small scroll compressor technology for industrial chillers. An important segregation (for benchmark levels only, not minimum requirements) occurs at 200 kW due to availability

from this capacity of flooded evaporators and VFD centrifugal chillers (the best of which also have magnetic bearings). A segregation for both benchmark and minimum requirements is proposed at 400 kW.

- For water cooled chillers it is common to find very efficient centrifugal chillers with VFD above 1000 kW and so different requirements are appropriate from that level, also with a lower segmentation at 400 kW (latter division as per air cooled chillers and for Lot 6).

7. Adjusted water leaving temperature

The leaving evaporator water temperature has been adjusted from 6°C to 7°C. This was specifically requested by the Joint Industry Expert Group (JIEG) and is in line with the commonly applied CEN Standards EN14511 / EN14825 and is in alignment with the full load performance of comfort chillers covered by the preparatory study DG-ENTR Lot 6: Air-conditioning and ventilation systems.

8. The case for two tiers, and timing

As discussed in the impact assessment study for low and medium temperature industrial process chillers, it is not appropriate to attempt to set more than two tiers of requirements into the future since the SEPR metric itself is new to the market and significant changes to typically deployed technologies are anticipated in the short to medium term. Conversely, a single tier only would either give manufacturers only short-term visibility of policy requirements and discourage appropriate investment, or would be set excessively far into the future with similar net effect. Hence, 2 tiers are proposed with timing to be decided but, as a starting point for discussion, suggested as Tier 1 after two years; Tier 2 after a further two years.

9. The case for ambitious minimum requirements

Available evidence suggests that there is a significant EU market failure to deploy efficient technologies that are demonstrably available on the market at investment levels that are easily justified economically. There is a marked contrast with air conditioning chillers in terms of economic viability since typical equivalent full load hours for HT industrial chillers are around 7500, compared to only 600 hours per year for typical air conditioning chillers. This is a factor of 12.5 higher usage - and 12.5 times annual running costs - for chillers often sold at similar initial investment costs. The market often does not differentiate between products sold for air conditioning and products sold for HT industrial process. Not only do these have very different annual total usage patterns but process chillers spend most of their time working at 80% or higher loading compared to air conditioning chillers often running at significantly lower loading. If the chiller design is carefully considered, different control and technology approaches would be appropriate for these two situations.

This market failure to deliver easily justifiable high-efficiency products is also supported by anecdotal evidence gained during the gathering of industrial chiller performance data:

- Whilst compressor designs incorporated in the products were often of reasonable or good efficiency, heat exchanger design often lead to significantly poorer SEPR levels than could be easily obtained with straightforward measures such as significantly

expanding exchanger surface area or having single pass heat exchangers to reduce pressure losses.

- Another example was from a major multinational chiller supplier that did not sell best performing large chillers into the EU due to lack of demand whereas this technology is well proven and cost-effective in commercially available products.
- In many cases, simple adjustments to the control algorithm or tweaks to the design tailored towards industrial process usage patterns would significantly raise achieved SEPR levels.

The analysis of cost effectiveness of measures carried out in the Lot 6 eco-design preparatory study is highly relevant to provide a baseline. But the equivalent full load hours of industrial chillers being 12.5 times as high as those for air conditioning chillers means that all efficiency improvement options and technologies considered under Lot 6 are extremely cost-effective for industrial applications. The economics for end users provide no theoretical or least life cycle cost barrier to deployment of the best performing currently available technologies. Consideration does of course have to be given to the costs to manufacturers of major product redesign and to the economics of design cycles.

10. Derivation of proposed minimum performance requirements

The case for setting minimum requirements based upon SEPR is discussed in the impact assessment study for low and medium temperature chillers and is accepted also for high temperature chillers.

A case has been made above for setting ambitious requirements to address the market failure. In order to set appropriate thresholds, consideration was given to:

a) the proportion of the market likely to be removed by proposed thresholds, combined with

b) careful consideration of the performance levels of available technologies to cross check how ambitious the levels might appear and to ensure product choice for end users will not be unduly reduced.

A starting point was taken that tier 1 might remove the poorest performing one third of the 2012 available models, and tier 2 would remove two thirds of the poorest performing 2012 models. This thinking was applied to the industrial chiller dataset, with the resultant levels subsequently adjusted upwards in several cases due to consideration that widely available technologies could easily meet the first indicative levels and that the second tier should impose impetus to stretch deployment of improved technologies rather than remaining within reach of basic technologies also able to meet Tier 1. The resulting levels are shown in Table 4.

Comparison of the proposed minimum requirements with the indicative 2012 market average SEPR levels shown in Table 4 suggests that the ambition to remove around one third of the market at tier 1 and two thirds of the market at tier 2 is met by these levels except for with larger water cooled units for which the tiers are slightly less ambitious but levels are justified when available technologies are considered.

11. Comparison of ambition levels with those for low and medium temperature industrial process chillers

It is apparent that the ambition level shown by proposed performance requirements for high-temperature industrial process chillers is significantly higher than that shown for medium and low-temperature chillers. The derivation approach has been significantly different, with high temperature requirements based on a more detailed examination of individual real product performance and technology options. Tier 1 for low and medium temperature chillers was accepted as removing only the poorest performing 5% to 10% of the market, with Tier 2 removing 11% to 20%. This compares with around 30% and 60% respectively for high-temperature chillers. The following issues support the proposed approach of accepting this difference and proceeding with that as it stands:

1. High temperature chillers account for around 80% of the industrial process chillers market and 70% of annual energy consumption. New technical and economic analysis of high temperature chillers identified a significant and cost-effective opportunity for ambitious mandatory energy performance requirements. (see section *'The case for ambitious minimum requirements: to address evident market failures'*).

2. It would impose significant additional technical and economic burden on manufacturers to redesign low, medium and high temperature industrial products over the same timescale.

3. More stringent requirements can be applied for low and medium temperature products with a far greater degree of confidence once more product SEPR performance data is available at the time of first regulatory review.

4. Expectations for future efficiency improvements for low and medium temperature products can be set through a closer examination of evidence to set appropriate benchmark performance levels that match the ambition of high-temperature requirements in a comparable and manageable timescale. (These would also be reviewed at the time of regulatory review).

5. Collating fresh evidence to enable an assessment of requirements for low and medium temperature chillers could further delay progress of the regulation.

The proposal thus aims to balance stringent requirements on manufacturers where energy savings are largest with less demanding requirements where sales and energy consumption are lower.

It is also appropriate to set more stringent requirements for industrial process chillers than those envisaged for conventional air conditioning chillers due to their much higher annual usage hours and high loading. Since process chillers generally operate all year round (over 7,500 equivalent full load hours per year), a significantly higher investment in energy efficiency measures is cost-effective compared to with air conditioning chillers that operate an average of only 600 equivalent full load hours per year.

Report compiled by Tait Consulting Limited and Center of Energy efficient Systems (CES), Armines

Figure 1. Air cooled chillers from the Eurovent dataset (cloud of green dots) showing net EER plotted against cooling capacity (kW) alongside EER for the submitted process chillers (larger blue dots). Left/right extent of horizontal dotted lines indicates the capacity range in each chiller family. Red and blue solid lines represent the Lot 6 proposed minimum EER requirements at 2015 and 2017.

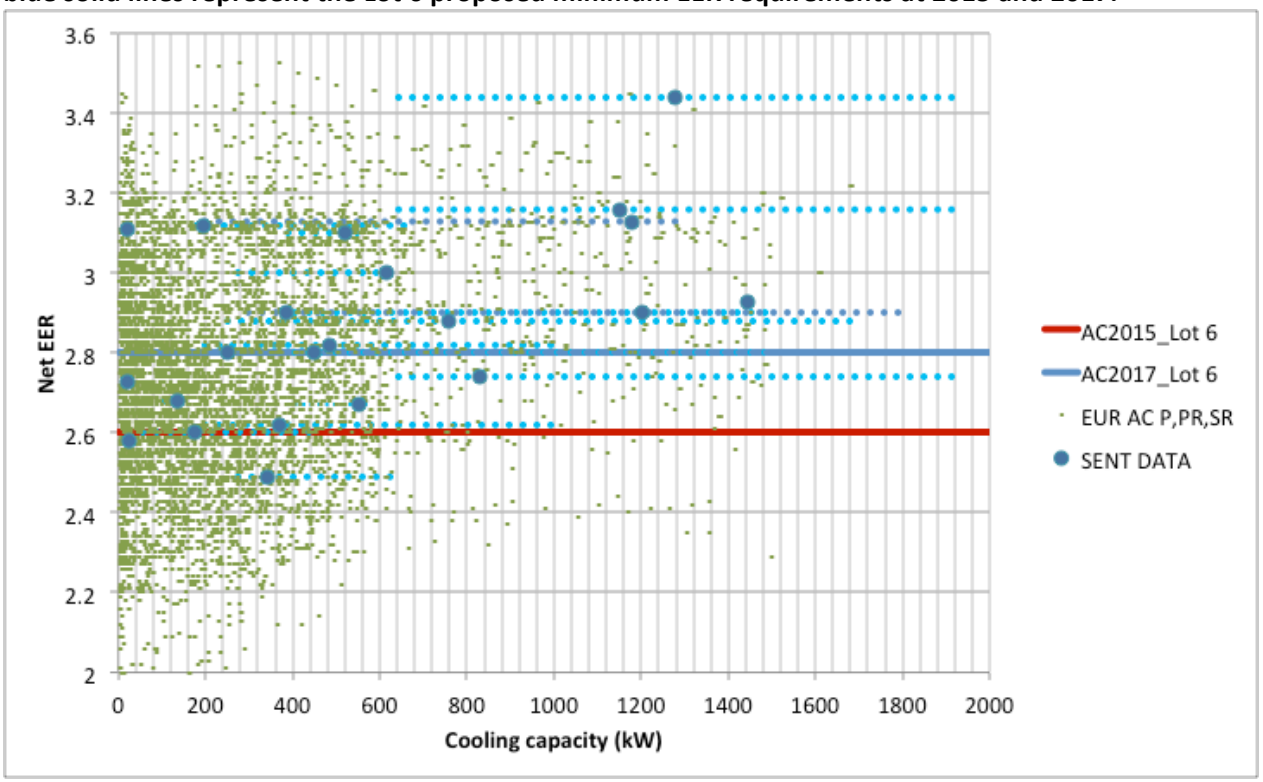

Figure 2. Water cooled chillers from the Eurovent dataset (cloud of blue dots) showing net EER plotted against cooling capacity (kW) alongside EER for the submitted process chillers (larger square dots). Left/right extent of orange dotted lines indicates the capacity range in each chiller family. Red solid line and green dotted line represent the Lot 6 proposed minimum EER requirements at 2015 and 2017.

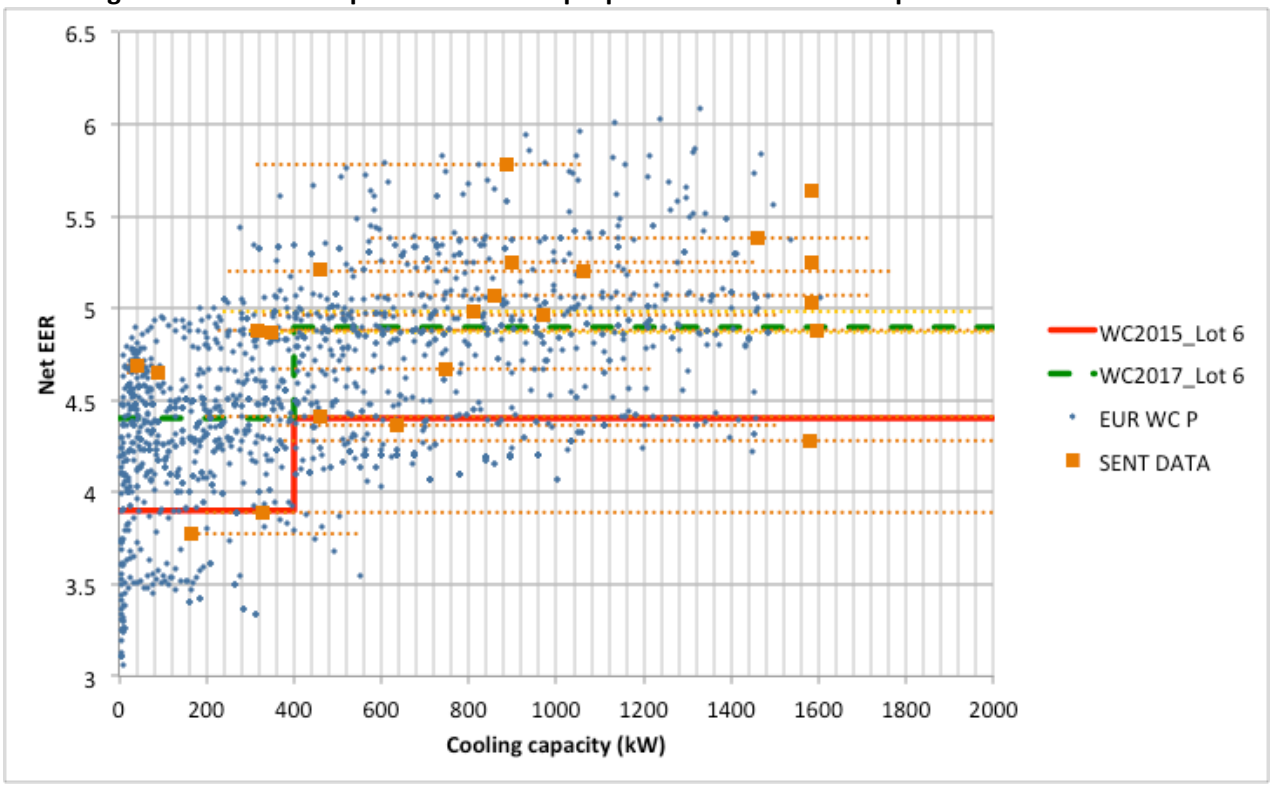

Table 1. Air cooled high temperature chillers: Comparison between median EER, ESEER and estimated SEPR for Eurovent dataset, and average EER, ESEER and calculated SEPR for the available process chiller dataset.

		Eurovent certification data set			Process chiller submitted data		
Capacity range, kW	Assumed Market average capacity for that range, kW	Median EER	Median ESEER	Estimated** average SEPR (IPC profile)	Average* EER	Average* ESEER	Average* calculated SEPR
<100 kW	40	2,7	3,8	4,91	2,8	3,6	4,58
>100 & <400 kW	250	2,7	3.8	4,91	2,7	3,8	4,73
>400 kW	1000	2,9	3.9	5,34	3,0	4,0	5,10

Table 2. Water cooled high temperature chillers: Comparison between median EER, ESEER and estimated SEPR for Eurovent dataset, and average EER, ESEER and calculated SEPR for the available process chiller dataset.

		Eurovent certification data set			Process chiller submitted data		
Capacity range, kW	Assumed Market average capacity for that range, kW	Median EER	Median ESEER	Estimated** average SEPR (IPC profile)	Average* EER	Average* ESEER	Average* calculated SEPR
<400 kW	250	4,4	5,4	7,14	4,5	5,3	7,31
>400 & <1000 kW	750	4,8	5,4	7,61	5,1	6,7	8,54
>1000 kW	1600	4,9	5,7	7,46	5,1	6,1	8,60

Key for Table 1 and Table 2:

* 'Average' is simple calculated average figure across all chillers in that capacity segment, regardless of technology type.

** 'Estimated' is derived using indicative ratios to convert EER into an SEPR figure according to the industrial process chiller (IPC) annual usage profile – see Annex 1 and Annex 2.

Table 3. Aspirational benchmark SEPR performance levels derived from the best EER levels seen in the Eurovent certification date set combined with consideration of available technology options.

	Capacity range, kW	Benchmark SEPR level
Air cooled	<200 kW	6,5
	>200 & <400 kW	8,0
	>400 kW	8,0
Water cooled	<200 kW	8,5
	>200 & <400 kW	12,0
	>400 & <1000 kW	12,5
	>1000 kW	13,0

Table 4. Proposed mandatory minimum SEPR performance levels.

	Capacity range, kW	Tier 1 minimum performance SEPR	Tier 2 minimum performance SEPR	*For comparison: Indicative average SEPR in 2012*
Air cooled	<400 kW	4,5	5,0	*4,7*
	>400 kW	5,0	5,5	*5,1*
Water cooled	<400 kW	6,5	7,0	*7,3*
	>400 & <1000 kW	7,5	8,0	*8,5*
	>1000 kW	8,0	9,0	*8,6*