The challenges of designing a NRVU-BVU for energy efficiency and enhanced IAQ

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Abstract. Directive 2009/125/EC establishes a framework for the setting of Ecodesign requirements for energy-using products. ‘Many products have a significant potential for being improved in order to reduce environmental impacts and to achieve energy savings through better design which also leads to economic savings for businesses and end-users’ [1]. Commission Regulation (EU) No 1253/2014, also known as Ecodesign directive 1253/2014/EC, applies to ventilation units and establishes ecodesign requirements for placing on the market or putting into service. The ecodesign requirements should be introduced gradually in order to provide a sufficient timeframe for manufacturers to re-design products subject to said regulation. This discussion paper highlights the practical challenges of designing a compliant non-residential bidirectional ventilation unit (NRVU-BVU) with the aim of improving energy efficiency whilst enhancing indoor air quality and discusses potential options to meet or exceed the requirements.

1. Introduction

Ecodesign directive 1253/2014/EC pushes building industry specialists (design engineers, consultants and manufacturers of residential and non-residential ventilation units, RVU’s and NRVU’s) to adopt solutions that favor lower air velocity, specific fan power, overall energy consumption and improved thermal energy recovery efficiency. ‘The timing should take into account the impact on costs for end-users and manufacturers, while ensuring that the environmental performance of ventilation units is improved without necessary delay’ [2]. The progressive implementation of ecodesign requirements is then characterised by two major step changes: ErP2016 Tier 1 and ErP2018 Tier 2. Each of these stages enlists a series of requirements that ventilation units have to comply with for their placing on the market or putting into service.

1.1 Ecodesign requirements for NRVU, from 1 January 2016 (ErP2016 Tier1)

‘All ventilation units, except dual use units, shall be equipped with a multi-speed drive or a variable speed drive. All bidirectional ventilation units shall have a heat recovery system. The heat recovery system shall have a thermal by-pass facility. The minimum thermal efficiency of all heat recovery systems except run-around heat recovery system in bidirectional ventilation units shall be 67%’ [2].

1.2 Ecodesign requirements for NRVU, from 1 January 2018 (ErP2018 Tier2)

‘All ventilation units, except dual use units, shall be equipped with a multi-speed drive or a variable speed drive. All bidirectional ventilation units shall have a heat recovery system. The heat recovery system shall have a thermal by-pass facility. The minimum thermal efficiency of all heat recovery systems except run-around heat recovery system in bidirectional ventilation units shall be 73%’ [2].
2. Challenges of designing NRVU-BVU – Worked Example

In practical terms it is not possible to meet Ecodesign requirements solely on technological innovation because the requirements fundamentally change the size, complexity and cost of the units for a given set of general conditions. In order to compare current requirements against ecodesigning an energy recovery unit in accordance to EU directives and its progressive implementation, a software tool (Visual AHU) was used to design three NRVU-BVU’s under identical general conditions.

2.1. Design of a NRVU under same general conditions

Balanced air flows of 2.0m³/s Supply & Extract; EC fans; ePM₁ 55% (F7) filter on supply; ePM₁₀ 55% (M5) filters on extract; Heat recovery component as cross-flow plate heat exchanger; One air heater; Outdoor air: 5Deg.C @ 50% RH; Exhaust air: 25Deg.C @ 0% RH (at EN308 air conditions [3]);

Table 1. Heat recovery unit (HRU) as per best practices in 2015

| Heat Recovery Unit (HRU) as per best practices in 2015 |
|--------------------------------------------------------|
| **HRU Design lay-out**                                 |
| **HRU Technical data**                                 |
| Length | Width | Height | Unit velocity | Total static pressure drop supply air | Total static pressure drop supply air |
| mm     | mm    | mm     | m/s           | Pa                                      | Pa                                      |
| 2980   | 1535  | 1320   | 2.26          | 487                                     | 459                                     |
| **Absorbed electrical power supply air**               |
| Absorbed electrical power extract air                  |
| Energy recovery                                       |
| SFP₁₁₀BVU                                           |
| kW | kW | % | kW/(m³/s) |
| 2.00 | 1.88 | 55 | 1.531 |

Table 2. NRVU-BVU as per ErP2016 Tier1

| Non-Residential Ventilation Unit – Bidirectional Ventilation Unit NRVU-BVU as per ErP2016 |
|-------------------------------------------------------------------------------------------|
| **NRVU-BVU Design lay-out**                                                              |
| **NRVU-BVU Technical data**                                                              |
| Length | Width | Height | Unit velocity | Total static pressure drop supply air | Total static pressure drop supply air |
| mm     | mm    | mm     | m/s           | Pa                                      | Pa                                      |
| 3080   | 1835  | 1420   | 1.72          | 439                                     | 412                                     |
| **Absorbed electrical power supply air**                                                 |
| Absorbed electrical power extract air                                                     |
| Energy recovery                                                                         |
| SFP₁₁₀BVU                                                                                |
| kW | kW | % | kW/(m³/s) |
| 1.58 | 1.48 | 67.5 | 1.168 |

Table 3. NRVU-BVU as per ErP2016 Tier3

| **NRVU-BVU Design lay-out**                                                              |
| **NRVU-BVU Technical data**                                                              |
| Length | Width | Height | Unit velocity | Total static pressure drop supply air | Total static pressure drop supply air |
| mm     | mm    | mm     | m/s           | Pa                                      | Pa                                      |
| 3080   | 1835  | 1420   | 1.72          | 439                                     | 412                                     |
| **Absorbed electrical power supply air**                                                 |
| Absorbed electrical power extract air                                                     |
| Energy recovery                                                                         |
| SFP₁₁₀BVU                                                                                |
| kW | kW | % | kW/(m³/s) |
| 1.58 | 1.48 | 67.5 | 1.168 |
Table 3. NRVU-BVU as per ErP2018 Tier2

| NRVU-BVU Design lay-out | Length (mm) | Width (mm) | Height (mm) | Unit velocity (m/s) | Total static pressure drop supply air (Pa) | Total static pressure drop supply air (Pa) |
|-------------------------|-------------|------------|-------------|---------------------|------------------------------------------|------------------------------------------|
|                         | 3530        | 1835       | 1860        | 1.28                | 343                                      | 325                                      |

| Absorbed electrical power supply air | Absorbed electrical power extract air | Energy recovery | SFP\text{int.BVU} (kW/(m$^3$/s)) |
|-------------------------------------|--------------------------------------|-----------------|-------------------------------|
| kW                                  | kW                                   | %               | kW/(m$^3$/s)                  |
| 1.26                                | 1.20                                 | 75              | 0.857                         |

| ErP Conformity | Energy recovery efficiency (%) | SFP\text{int.BVU}(kW/(m$^3$/s)) | ErP 2018 |
|----------------|-------------------------------|---------------------------------|-----------|
| Real value     | Max value                     | Real value                     | Max value |
| 2016           | ≥67%                          | ≥73%                           | 0.857     | ≤1.40 ≤1.30 |

This comparison shows that a non-residential bidirectional ventilation unit that was designed in 2015 differs significantly to a solution that complies with ecodesign directives.

3. Analysis - Impacts and benefits associated with ErP compliant NRVU-BVU’s
At present, the design of a NRVU-BVU is directly connected to two main ecodesign requirements: thermal energy recovery efficiency and specific fan power. Combined, these two requirements impact on four distinct areas.

3.1. Unit footprint
Unit velocity and overall footprint are severely impacted by the ecodesign requirements, with the latest seeing an increase of up to 68% of the unit cross-section for Tier 2 against a 2015 unit design. To achieve the thermal energy recovery efficiency threshold for Tier 2, the physical size of the energy recovery component alone (in this case a crossflow plate heat exchanger), sees an increase of up to 57% vs the older design, as shown in the following Table 4.

3.2. Cost
An increase in investment cost related to an increase in cost of the unit and floor space should be anticipated at building design stage. The following table shows increase in the material cost of the units alone. The size increase will also inevitably lead to increased cost of transport and installation.

Table 4. Comparison between 2015, ErP2016 Tier 1 and Erp2018 Tier 2 design

| ErP-Directive | Tier 1 - 2016 | Tier 2 - 2018 |
|---------------|---------------|---------------|
| Overall Unit Footprint | W x H (mm); 2015 design: 1535mm x 1320mm | 1835mm x 1420mm | 1835mm x 1860mm |
| Increase of unit cross-section compared to 2015 design (%) | 29% | 68% |
| Investment costs | Increase of PHE size (length) compared to 2015 design (%) | 28% | 57% |
| Increase in overall unit cost compared to 2015 design (%) | 15% | 33% |

3.3. Energy efficiency
Efficiency gains will result in energy savings and significant reductions in running costs.
Table 5 shows that by ecodesigning a NRVU-BVU for Tier 2 compliance, can lead to a significant 37% reduction in energy usage (reduction in fan absorbed power) and 20% increase in thermal energy recovery which reduces heating costs.

| Table 5. Comparison between ErP2016 tier1 and Erp2018 Tier2 energy efficiency |
| --- |
| **ErP-Directive** | **Tier1 - 2016** | **Tier2 - 2018** |
| Overall Unit Footprint | 1835mm x 1420mm | 1835mm x 1860mm |
| Energy consumption | Reduction in fan absorbed power compared to 2015 design (%) | 21% | 37% |
| | 12 month fan run cost compared to 2015 design (£2,379.22)* | £1,876.39* | £1,508.47* |
| | £502.83 saved per year | £870.75 saved per year |
| Energy recovery | Increase in energy recovery compared to 2015 design (%) | 12.5% | 20% |
| | 12 month energy recovered (26.8kW) compared to 2015 design (£14,433.76)* | £3,801.84 saved per year | (£36.4kW) £22,320.48* |
| | £876.72 saved per year |

*Fixed tariff at 14p; Running time of 12hrs per day for 12months

3.4. Indoor air quality

Air filters are integral components of any type of air handling unit which significantly influence the indoor air quality and, hence, the health of people by reducing the concentration of particulate matter present in the air. ‘Particulate matter in the context of the ISO 16890 series describes a size fraction of the natural aerosol suspended in ambient air’ [7]. To enable design engineers and maintenance personnel to choose the correct filter types for each application, BS EN ISO 16890 ‘filters are evaluated by their ability to remove aerosol particulates expressed as the efficiency values: ePM10, ePM2.5 and ePM1’ [7]. The recommended minimum efficiencies depending on outdoor air (ODA) and supply air (SUP) categories can now be presented as [9]:

| Table 6. Recommended minimum ePMx filtration efficiencies depending on ODA and SUP categories. Annual mean PMx values in µg/m³ [9] |
| --- |
| **Outdoor air** | **SUP1** | **SUP2** | **SUP3** | **SUP4** | **SUP5** |
| Category | PM2.5 | PM10 | PM2.5 | PM10 | PM2.5 | PM10 | PM2.5 | PM10 | PM2.5 | PM10 |
| ODA1 | ≤10 | ≤20 | 70% | 50% | 50% | 50% | 50% | 50% |
| ODA2 | ≤15 | ≤30 | 80% | 70% | 70% | 80% | 50% | 50% |

*Minimum filtration requirements ISO ePM10, 50% refers to a final filter stage; **Minimum filtration requirements ISO ePM2.5, 50% refers to a final filter stage;

4. Discussion - The Reality

Although progressively enforced, all ecodesign parameters are intrinsically connected and to strike the right balance between product compliance and market/customer needs means that during product development stages, digital tools such as Visual AHU software are key. Image 1(a), 1(b) and 1(c) depict the challenge and progressive changes of ecodesigning a new NRVU-BVU. Image 1(a) shows an energy recovery unit against 2015 best practice. This old design allows the unit to be as compact as it can be with no cap on fan absorbed powers or efficiency levels of energy recovery. Under the same general conditions but integrating ecodesign requirements for Tier 1 - ErP2016, Image 1(b) clearly shows a fully compliant new product with an increased unit cross-section, increased size of the energy recovery component and consideration taken to the usage of finer filtration. Tier 2 – ErP2018 ecodesign requirements are then integrated into the design of a new NRVU-BVU as shown in Image 1(c). Here the new unit has achieved a reduction in fan absorbed power of up to 37% equating to an energy saving of £871.00 per year. However, its cross-section was inevitably increased by 68% to achieve the same mass air flow.
An innovative approach to ecodesigning a new ventilation unit is paramount to achieve the ultimate goals: maximise airflow whilst minimising energy usage, achieve high levels of thermal energy recovery efficiency during summer and winter, minimise energy required to maintain good thermal comfort within the occupied space, enhance indoor air quality by removing outdoor air pollutants (dust & gas) and bring in clean fresh air only when necessary (via demand controlled or smart ventilation). This unique combination of features and benefits can then be amplified by a fully integrated indoor air quality and energy recovery management device that controls and monitors the operation of a new NRVU-BVU.

However, the reality of this scenario remains challenging as there is still a lack of awareness from the industry specialists (building design engineers, consultants, building contractors and end users), to accept that in order to meet with Ecodesign requirements, the ventilation units require bigger footprints. This is required to allow for lower air velocities, lower component pressure drops, lower fan absorbed power and maximise efficiencies on thermal energy recovery components as well as enhanced filtration to tackle current levels of outdoor air pollutants.

‘Improving the energy and resource efficiency of products contributes to the security of the energy supply and to the reduction of the demand on natural resources, which are preconditions of sound economic activity and therefore of sustainable development’ [1].

5. Conclusions

Ventilation units, account for a large proportion of the consumption of natural resources and energy, the benefits of implementing ErP and Ecodesign directives are definitely positive and outweigh the need to compromise in floor space, which should be taken into consideration during design stage of the whole project. Often these are only considered only when construction has already begun, when changes to floor space are difficult or impossible to accommodate.

The framework set out by EU directives is sure to drive innovation to maximise energy savings through ecodesigning new energy-related products of which ventilation units are an integral part. By integrating all ecodesign requirements at an earlier stage in the development process, manufacturers of ventilation units can offer a solution to support nearly-zero energy building projects.

In a nearly-zero energy building, energy saving maximisation can still be enhanced by adopting innovative ventilation strategies such as demand controlled and intelligent ventilation, real-time monitoring and smart maintenance. Combining these strategies together means fitting robust indoor air quality and energy recovery management devices that can automatically adjust the operation of the ventilation unit according to occupancy levels, indoor/outdoor pollution levels whilst reducing system running costs. Choosing to use real-time monitoring and smart maintenance will also guarantee that the new building retains its nearly-zero energy status, continuously delivering healthy indoor quality air and thermally comfortable usable spaces for all its users throughout its entire life time.
References
[1] Directive 2009/125/EC of the European Parliament and the Council of 21 October 2009, establishing a framework for the setting of ecodesign requirements for energy-related products;
[2] Commission Regulation (EU) No 1253/2014 of 7 July 2014, implementing Directive 2009/125/EC of the European Parliament and the Council with regard to ecodesign requirements for ventilation units;
[3] BS EN 308:1997 – Heat exchangers; Definition and test procedures;
[4] BS EN 13779:2007 – Ventilation for non-residential buildings; Performance requirements;
[5] BS EN 1886:2008 – Air Handling Units; Mechanical performance;
[6] BS EN 13053:2011 – Ratings and performance for units and components;
[7] BS EN ISO 16890:2016 – Air filters for general ventilation;
[8] BS EN 16798-3:2017 – Energy performance of buildings; Ventilation for buildings;
[9] Eurovent REC 4/23 – Selection of EN ISO 16890 rated air filter classes for general ventilation applications, 2nd Edition, Published 1 October 2018;