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Screening of IEQ content in five building certifications

An overview of indoor environmental quality content and weights in five building certification schemes for dwellings

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Publication date:
2022

Document Version
Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

Citation for published version (APA):

Rohde, L., Bekö, G., & Guglietti, A. (2022). *Screening of IEQ content in five building certifications: An overview of indoor environmental quality content and weights in five building certification schemes for dwellings*. Institut for Byggeri, By og Miljø (BUILD), Aalborg Universitet. BUILD Rapport Vol. 2022 No. 30

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Screening of IEQ content in five building certifications

An overview of indoor environmental quality content and weights
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TITLE	Screening of IEQ content in five building certifications
SUBTITLE	An overview of indoor environmental quality content and weights in five building certification schemes for dwellings
SERIES TITLE	BUILD Report 2022:30
FORMAT	PDF
EDITION	1st Edition
YEAR OF PUBLICATION	2022
DIGITAL PUBLICATION	December 2022
AUTHORS	Lasse Rohde, Gabriel Bekö, Ambra Guglietti
LANGUAGE	English
NUMBER OF PAGES	22
KEYWORDS	Indoor Environment Quality, Thermal Comfort, Indoor Air Quality, Acoustics, Visual Comfort, Building Certification, Dwellings
ISBN	978-87-563-2063-4
ISSN	2597-3118
PHOTO	VELUX A/S
PUBLISHER	Department of the Built Environment, Aalborg University, A.C. Meyers Vænge 15, 2450 Copenhagen SV E-mail: build@build.aau.dk www.en.build.aau.dk

Content

Preface	4
Content of this report	4
1.0 Selected Certifications	5
1.1 Presentation of Selected Certifications	5
2.0 Comparison	8
2.1 Comparison procedure	8
2.2 Assessment Content	9
2.3 Weighting and Scoring	12
Conclusions	19

Preface

This report is part of the deliverables within the project PRJ-2021-00199 funded by Realdania. The project is a collaboration between Danish universities, real estate companies and building materials manufacturing companies to lay the foundation for adapting the recently developed **IEQCompass** to single-family houses. The **IEQCompass** is a certification scheme that evaluates the potential of a building to provide a comfortable and healthy indoor environment. It was initially developed for multifamily social housing, and its adaptation, relevance and feasibility within other building types will be evaluated.



Content of this report

- This report compares the existing version of the **IEQCompass** scheme with other certification programs focusing on the indoor environment of residential buildings.
- The investigated certifications were selected among the large number of existing building certification schemes considering the role of indoor environmental quality in the overall certification, the applicability for dwellings (mainly single-family homes) and the relevance for the Danish context.
- The report compares the indoor environmental quality aspect, structure, content and weighting of five selected certification schemes.

1.0 Selected Certifications

1.1 Presentation of Selected Certifications

The following contains a brief introduction to the five selected certifications. The texts below are mainly based on the official websites and manuals for each certification, but also reports and papers about a few of the certifications. Table 1 below presents the certifications at a glance. Detailed analyses of the certification schemes will follow in section 2.0 Comparison.

HQM (Home Quality Mark, BREEAM)

The Home Quality Mark (HQM) was developed as part of the BREEAM family of schemes to assess sustainability in the built environment. HQM benefits from decades of experience and research in evaluating and certifying high standards of homes and other buildings within the UK and the rest of the world. However, HQM is an independently assessed certification scheme for new homes. It awards certificates with a simple star rating for a home's design, construction and sustainability standard. It has an increased focus on improving the built quality of new homes and reducing the performance gap. It is designed to provide a trusted mark of quality that consumers can trust and housebuilders, developers and housing providers can benefit from. It indicates to householders the expected running costs, health and well-being benefits, and the environmental footprint associated with living in the home. It also highlights benefits such as access to local amenities and the quality of the local neighbourhood. HQM can currently be used to assess the environmental, social and economic impacts of newly built homes in England, Wales and Scotland only. (A brief guide to the Home Quality Mark, V0.0, January 2020; www.homequalitymark.com)

NORDIC SWAN Ecolabel

The Nordic Swan Ecolabel is a well-known and well-reputed trademark in the Nordic region. It covers not only environmental issues but also quality requirements since the environment and quality often go hand in hand. It meets strict obligatory requirements for the whole life cycle of the building, including extraction and production of materials, the construction process, the use phase as well as the waste and recycling phase. The requirements help to promote a circular economy, reduce climate impact, save resources and preserve biodiversity. It also promotes high-quality buildings with good indoor environment. The Nordic Ecolabelling makes requirement of the building's energy use, chemical products, building products/goods and a number of indoor environmental factors that are relevant to health and the environment. The Nordic Ecolabelling also makes requirements of quality management in the construction process and the handover of the building to the residents and administration/operations. It can currently be applied to small houses (single-family houses, row houses, terraced houses, detached and semi-detached houses), apartment buildings, educational buildings and elderly homes and holiday homes. This scheme is seen as a holistic label for building structures due to its balance between requirements of low energy consumption, environmental and health requirements on construction products, materials and chemical products, requirement of good indoor environment and low emissions and requirement of a quality-assured construction process. The scheme has been recently revised in light of requirements related to national laws, regulations and norms in order to facilitate the roll-out of the same concept in several countries. (Nordic Ecolabelling for New Buildings, Version 0.0, 12 January 2022 – 15 March 2022, consultation version)

DGNB VILLA

DGNB is a German certification founded in 2007 by a multidisciplinary team of experts seeking to promote sustainable building from a broader perspective. DGNB was the first to give Economic and Social aspects equal weighting as the Ecological and even went beyond the three pillars of sustainability of the Rio Declaration to also include Technical Quality and Process Quality. DGNB is a total value sustainability assessment. It is 'a human-centred assessment tool' with indoor environmental performance being the most significant contributor to Social Quality, making up a considerable part of the overall assessment. DGNB-Villa is the latest edition of the DGNB certification, reflecting further development of the certification scheme after taking into account the feedback and experience from the market and various related projects. DGNB-Villa aims to put more focus on good indoor climate and low climate footprint. It constitutes a separate part of the DGNB family of certifications and focuses on sustainability certification of single-family homes. Through 12 criteria, grouped under the main qualities Environment, Economy and Social, and associated sub-topics and indicators, it makes it possible to evaluate individual buildings based on a common set of criteria and ensure one unique, measurable standard for all buildings certified according to the scheme. (www.dgnb.de; dk-gbc.dk; Rohde et al., Comparison of Five Leading Sustainable Building Certifications Concerning Indoor Environmental Assessment Content, Aalborg University, DCE Technical Reports No. 269; DGNB Villa Manual, Pilotversion 2022)

TAIL

TAIL is a new IEQ rating scheme, creating a framework for rating IEQ components and the overall IEQ level in a building during its normal use. The acronym TAIL stands for the thermal environment (T), acoustic environment (A), indoor air quality (I), and luminous (L) environment. The TAIL rating scheme is not an official certification scheme. It is the first step in developing an integrated index characterising IEQ in buildings standardised at the EU level. TAIL is intended to classify and compare IEQ and its components before and after an energy renovation and to document the impact of energy renovation on IEQ. It has been mainly designed for rating indoor environmental quality in offices and hotels undergoing deep energy renovation. TAIL attempts to address the lack of a standard set of parameters to characterise IEQ in buildings during regular use, especially focusing on energy renovations. It is supposed to comply with existing standards and Green Building schemes that address IEQ. The method is based on objective measurements because occupant surveys, although valuable and useful, may not be easy to implement and do not have the repeatability and rigour achieved by measurements of physical and chemical parameters. Wargocki et al., TAIL, a new scheme for rating indoor environmental quality in offices and hotels undergoing deep energy renovation (EU ALDREN project), Building and Environment 244, 111029, 2021)

IEQ-Compass (IK-kompas)

IEQCompass is a tool to holistically evaluate and effectively communicate the potential IEQ in multifamily residential buildings nationally in Denmark. However, the overall framework is versatile; the tool can be adapted for other building types, such as offices, schools and single-family homes, and different regions. The tool is applicable both in new and renovated buildings and can be used to evaluate design proposals. It aims to facilitate a broader understanding of IEQ and its importance for comfort, health and well-being and to promote IEQ considerations in renovation strategies in response to the growing need for deep renovations at a European level. This tool aims to facilitate a broader understanding of IEQ, its importance for comfort, health and well-being, and to guide the building design process regarding IEQ. The tool evaluates the potential indoor air quality (IAQ), thermal, visual and acoustic IEQ without considering user influence. The scheme is based on relevant criteria assessed from blueprints, existing building information modelling data or observations during building inspection. The labelling scheme uses letter ranking and colour code similar to energy performance certification. The tool's original name is in Danish (IK-kompas), but its English name, as published before, is used in this report. (Larsen et al., IEQ-Compass – A tool for holistic

evaluation of potential indoor environmental quality, Building and Environment 172, 106707, 2020; IK-kompas Etageboliger – værktøj til holistisk vurdering af indeklima, BUILD Rapport 2021:04)

Table 1 At glance facts for the five certifications selected for analysis in this report

Acronym / Full Name	Version Analysed	Institute / Origin / Certification launch
HQM	Issue 0.0, 2018	BRE Global Ltd. . Building Research Establishment, United Kingdom. HQM is part of the BREEAM family. HQM ONE builds on the beta version of the scheme, which has been operating since early 2016.
Nordic Swan	Version 3.15	Nordic Ecolabelling, Denmark, Sweden, Norway, Finland, Iceland; April 2022
DGNB-Villa	Pilotmanual 2022	Green Building Council Denmark. DGNB-Villa certification and manual builds on the existing DGNB-system, but aim to create a simplified certification scheme for single-family houses
TAIL	As described in Wargocki et al., 2021	EU Project Aldren, ALliance for Deep RENovation in buildings, November 2017 – October 2020, https://aldren.eu/ ; 2021
IEQ-Compass	Manual, 1. edition, January 2021	Rebus Project, Denmark; 2022

2.0 Comparison

2.1 Comparison procedure

Documents describing the selected certification schemes were obtained from the web or directly from responsible authorities. Only in the case of HQM, the final documentation for the complete scheme was available. Nordic Swan and DGNB Villa were under development at the beginning of this project, and preliminary documentation was obtained and screened. The evaluation was later updated as new (and final) document versions were acquired later. Our group has developed **IEQCompass**. It is currently under the final testing phase, and the most recent documents were screened. As part of the developing team, our group also has a profound knowledge of this scheme, the further development of which is the main reason for this report. TAIL is a concept described in a peer-reviewed article, the only source used to evaluate it for this report.

The screening of the available documentation followed the methods described in Rohde et al. (2019). We extracted detailed information on the assessment content (main indoor environmental categories such as thermal IE, visual IE, acoustic IE and indoor air quality), covered parameters, scoring system, weighting, aggregation of points, minimum requirements, and other potential requirements.

Certification structures were mapped for each certification in a combined table, including topic levels, weighting factors, accumulation of points, certification levels and additional requirements. Each certificate has its unique set of terms, making comparison difficult. We grouped the considered parameters in groups of categories reported in Table 2. For schemes that do not explicitly focus on indoor environment, we also present the indoor environmental content in general relation to the overall content of the scheme (underlined text in Table 3).

We present the combined influence of all IE areas on the overall score of the complete certification (whenever applicable). This is done by adding the maximum points obtainable for IE topics in a given certification multiplied by their weights (if any) and comparing this to the theoretical maximum total score for that certification. The purpose of this index is to show the overall focus of each certification at a glance (Table 5).

2.2 Assessment Content

Indoor Environmental Content

Table 2 shows a content overview of the five certifications grouped into five categories: Thermal indoor environment (IE), Indoor Air Quality, Visual IE, Acoustic IE, and User influence. The content categories in Table 2 are based on the combined content of the five certifications. Similar parameters were merged for ease of comparison between the certifications; specific definitions of some of the parameters may differ slightly between the individual schemes.

Content Comparison on IE Main Area Level

There are both overlaps and differences between the certification schemes regarding the parameters being covered. However, since all schemes have been designed to achieve a good indoor environment or assign a significant role to it in the overall certification, four of the five schemes cover the majority of the listed parameters each. The significantly different scheme is TAIL, which relies exclusively on measurements.

Thermal IE considers summer and winter temperatures, the presence of cooling, and precautions regarding draft. None of the schemes covers all these parameters, but HQM covers all but draft. IEQCompass covers most, including drafts, but does not require monitoring of thermal parameters. DGNB-Villa is limited to summer temperatures, drafts specifically from mechanical ventilation, and excludes monitoring. TAIL and Nordic Swan, on the other hand, are entirely based on physical measurements of air temperature and relative humidity (the latter being considered under IAQ).

Under **Indoor Air Quality**, ventilation is considered in either measurements or ventilation strategy evaluation by all schemes. Air filtration (standard compliance, commissioning) and the application of low-emitting materials are included in all schemes but TAIL. The use of pollution maps (mostly particles and, in some cases, radon) is only part of IEQCompass. DGNB-Villa and IEQCompass consider source control for air pollutants from construction work (e.g. air duct handling before instalment, flushing of newly built space, etc.) and/or from combustion processes (fireplaces, boilers, heaters etc.). Measurements of air pollutant levels (especially volatile organic compounds, formaldehyde and radon, although the list of included compounds differs between the schemes) are an integral part of all schemes except Nordic Swan and IEQCompass; The latter has been strictly designed not to include monitoring. IEQCompass and TAIL treat air humidity as an indoor air pollutant. The former gives credit for humidity control via ventilation or source control, and the latter requires measurements.

Visual IE contains the factors daylight (quantity, distribution, quality), sunlight, view out (access to view, view angle, obstruction of view) and view in (risk of reduced privacy). IEQCompass is the only scheme that takes into account all these parameters. Nordic Swan considers only daylight quantity. HQM scores the quantity and distribution of daylight (although not quality indicators such as colour rendering or visual balance/brightness management) and view out. DGNB-Villa scores all three aspects of daylight but no other parameters. TAIL requires the measurement of illuminance and simulation of the daylight factor (both quantitative indicators of daylight).

The **Acoustic IE** is well covered by most of the certification schemes. While TAIL requires the measurement of sound pressure level (airborne sound), all other schemes evaluate airborne sound (noise from traffic, neighbours, other indoor sources) and impact sound (from construction such as floors, staircases). Reverberation time is only considered by DGNB Villa and IEQCompass, while background noise (e.g. from ventilation system), privacy and zoning (e.g. noise through internal walls, sleep disturbance) and ambient noise (measured or judged from noise maps) are taken into account also in HQM. It should be noted that IEQCompass treats privacy and zoning only through the availability of windows on the quiet side of the

building. Nordic Swan is mainly based on national standards and considers only airborne sound and impact sound.

The schemes differ in terms of their emphasis on **User influence**. **IEQCompass** is the most comprehensive in this regard, assessing the availability of forced ventilation for dynamic occupancy, operable windows, adjustable temperatures at room level, adjustable solar shading and cooling, and the occupants' possibilities to adjust the acoustic IE. **IEQCompass** does not require a user manual informing users about technical systems concerning IEQ. DGNB-Villa and HQM do recommend user manuals. The former assesses the presence of operable windows, adjustable temperatures at room level and adjustable solar shading, while the latter assesses only adjustable temperatures on room level and the availability of forced ventilation for dynamic occupancy. TAIL does not consider user influence.

Table 2 Content overview of the five certifications regrouped into five IE categories: Thermal IE, IAQ, Visual IE, Acoustic IE, and User influence

Category	Description	HQM	Nordic Swan	DGNB-Villa	TAIL	IEQ-Compass
Thermal						
Temperatures, summer	Overheating (based on calculation or simulation)	x		x		x
Temperatures, winter	Low-temperature threshold, heat source control and/or surface temp.	x				x
Cooling	Cooling/air conditioning (precautions concerning drafts and humidity)	x				x
Draft	Drafts (winter/summer, e.g. downdraft, leaky opening, cold intake air)			x		x
Monitoring	Monitor thermal parameters (e.g. air temperature, relative humidity)	x			x	
IAQ						
Ventilation	Ventilation rate (quantity), Intake/exhaust position, Ventilation strategies (natural, mechanical)	x	x	x	x	x
Filtration	Air filtration (standards for installed filters, commissioning)	x		x		x
Pollution mapping	Particle pollution maps (site), optionally radon concentration maps					x
Air quality tests / monitoring	Pre-occupancy or post-occupancy measurements (e.g. VOCs, Formaldehyde, Radon, CO2, Benzene, PM2.5, relative air humidity)	x		x	x	
Low-emission materials	Materials labelled for low-emission (VOCs, SVOCs, formaldehyde)	x	x	x		x
Humidity control /inspection	Humidity controlled ventilation (shower), source control: drying clothes, bathroom ventilation control	x				x
Pollution source control	Pollution from construction work (duct sealing, filter replacing, flushing) & combustion processes (fireplaces, boilers, heaters etc.)			x		x
Visual						
Daylight (quantity)	Daylight (quantity)	x	x	x	x	x
Daylight (distribution)	Daylight (distribution, including penetration and room depth)	x		x		x
Daylight (quality)	Daylight (colour rendering (Ra), visual balance/brightness management)			x		x
Sunlight exposure	Sunlight exposure (quantity - as a positive contribution)					x
View out	View out (quantity - access to view, view angle; obstruction from solar shading, worst case)	x				x
View in	View in (risk of reduced privacy from exposure to views from outside)					x
Acoustic						
Airborne sound	Sound insulation levels (noise from traffic, neighbours, other rooms)	x	x	x	x	x
Impact sound	Impact sound (floors, stairs and balconies)	x	x	x		x
Reverberation time	Reverberation time (inside dwelling)			x		x
Background noise	Background noise (HVAC, external noise intrusion)	x		x		x
Privacy and Zoning	Privacy and zoning (internal walls, bedrooms, loud/quiet/mixed zones)	x		x		x
Noise measurement /mapping	Ambient noise measurements, or the use of existing noise maps	x		x		x
User influence						
Ventilation boost	Forced ventilation rate in rooms with dynamic people loads (easy to use)	x				x
Operable windows	Operable windows (manual or mechanical with override)			x		x
Temperature regulation	Adjustable temperatures at room level	x		x		x
Adjust. shading	Adjustable external solar shading (e.g. window-by-window activation, for view out or thermal effects)			x		x
Cooling system	Adjustable set points, on/off, remote control					x
IEQ user manual	User manual that informs about technical systems concerning IEQ	x	x	x		
Occupant acoustic adjustments	Possibility to open windows in multiple directions (away from noise)					x

2.3 Weighting and Scoring

Certification Structure

Tables 3 and 4 summarise the contents and structure of the five certification schemes, focusing on IEQ. The underlined information in Table 3 indicates data specifically concerning IE assessment. HQM, Nordic Swan and DGNB-Villa do not evaluate indoor environment quality only.

HQM is built around three key areas of concern, one of them being "MyWellbeing", which covers indoor environment. This main IE category contributes 30% to the overall scheme. Out of 39 "Issues" covered in the scheme, 17 are related to "My Home" section, of which six are related to indoor environment. HQM provides a Star Rating and Indicator Score based on the total number of scores. In the Star Rating, 1 star is given to a home that meets the minimum standard requirements, while five stars are assigned to a home that achieves at least 400 of the total of 500 credits (80%). Indicator Scores (1-5) are given to each of the three key areas of concern. Score 1 requires a minimum of 18% of the total number of points, and score five a minimum of 80%. The maximum number of points is 283.5 for MyWellbeing, 262.5 and 400.75 for the other two key areas ("MyCost" and "MyFootprint").

Nordic Swan covers seven "Areas", one of which is on indoor environment. This Area constitutes 14% of the total scheme, which consists of forty-one obligatory requirements and 14-point score requirements. These are not evenly distributed across the seven Areas. The point scores are summed, and on top of the obligatory requirements, a minimum score has to be achieved to obtain the label. For Denmark, the minimum score for small houses is 16 points (out of the total of 42 relevant points), for apartments 17 points (out of 44), and for educational buildings, it is 15 points (out of 39).

DGNB-Villa covers 3 "Qualities"; one of them ("Social Quality" with a weight of 30%) covers IEQ. Three of the 12 criteria within the Qualities are related to IEQ, assessed through 6 "Criteria Indicators". The overall score ("Total Performance Index") is calculated based on the achieved and available Criteria Indicator points corrected with weight factors. DGNB-Villa provides certification in the form of a scorecard showing the "Performance Index" (a number, min. 50 required) and 1 to 5 stars for each of the three Qualities.

In contrast, TAIL and **IEQ**Compass have been designed to assess IEQ only. Each covers four main "Components"/"Areas" (thermal IE, acoustic IE, visual IE and IAQ). While these are weighted equally in **IEQ**Compass, the overall quality level for the building in TAIL is determined by selecting the lowest quality level among the four Components. TAIL covers 12 "Parameters" (of which 8 are IAQ-related), **IEQ**Compass evaluates 16 Parameters, 4 for each "Area", and each Parameter is scored based on 1-6 "Criteria". The Criteria are weighted towards a Parameter score, and Parameters are weighted toward an Area score. TAIL does not sum or weight points but calculates interim ratings from the measured values. TAIL provides an overall rating from I (high/desired quality level) to IV (low/undesirable) quality level). **IEQ**Compass provides a letter rank (A-G) and colour code similar to existing energy certifications, corresponding to specific ranges in the overall scores (1-100%).

Table 3 Overview of content structure for the five analysed certification schemes, and indication of IE-specific content (underlined)

	Topic groups	Main topics	Weighting factors	Sub-topics (with points)
HQM	3 key areas of concern <u>1 key area "My Well-being" (IE)</u>	39 Issues <u>6 Issues (IE)</u>	Key areas weights (30%, 42% and 28% respectively) <u>Well-being 30% (IE)</u>	39 Issues Issues contribute differently to the 3 key areas (9 Issues contribute to Well-being) <u>6 Issues (IE)</u>
Nordic Swan Ecolabelling	7 Areas <u>1 Area (IE)</u>	41 "O" Obligatory requirements 14 "P" Point score requirements (up to 44 points)	The areas have different weights in terms of point score <u>14% (IE)</u>	41 Obligatory Parameters distributed across the 7 Areas, the 14-point scores are not evenly distributed in each Area <u>6 out of the 41 "O" criteria (IE)</u> <u>4 out of the up to 44 points available (IE)</u>
DGNB-Villa	3 Qualities <u>1 Quality (IE)</u>	12 Criteria <u>3 Criteria (IE)</u>	Quality Weights (40%, 30% and 30% respectively) <u>Social Quality 30%</u>	Criteria Indicators 24 Criteria Indicators, with several sub-indicators (varying amount of points) <u>6 Criteria Indicators (IE)</u>
TAIL	IEQ only	4 Components <u>4 Components</u>	N/A the overall quality level is determined by selecting the lowest quality level among the 4 TAIL Components	12 Parameters (no points - the lowest interim rating of parameters determines the quality level of the Components) <u>12 Parameters</u>
IEQ-Compass	IEQ only	4 Areas <u>4 Areas</u>	The 4 areas are equally weighted (25% each)	16 Parameters; 4 Parameters per Area weighted 5-35% each within a given area; each Parameter evaluated based on 1-6 Criteria, weighted 5-100% each within a given Parameter. Each Criterion can obtain a 0-10 score <u>16 Parameters; 4 Parameters per Area</u>

Table 4 Overview of scoring structure and certification for the five analysed certifications schemes

	Sum of points	Certification	Additional requirements
HQM	<p>Star Rating (5-star system): 1 star = a home that meets key baselines beyond min. standards, 5 stars = a home pushing the boundaries. Max 500 credits are available within the 39 Issues.</p> <p>The Indicator scores for each of the 3 key Areas of concern: 262.5 for MyCost 283.5 for MyWellbeing 400.75 for MyFootprint</p> <p>(considering the weighted contribution of each issue to the 3 key areas)</p>	<p>HQM Certification Star Rating</p> <p>1 star= min req. only 1.5 star= min 90 credits (=18%) 2 star= min 100 credits (=20%) 2.5 star= min 120 (=24%) 3 star= min 150 (=30%) 3.5 star= min 190 (=38%) 4 star= min 240 (=48%) 4.5 star= min 300 (=60%) 5 star= min 400 (80%)</p> <p>Indicator scores</p> <p>In each of the 3 key Areas you score: 1= min 18% 2= min 20% 3= min 30% 4= min 48% 5= min 80%</p>	
Nordic Swan Ecolabelling	<p>The point scores can be all summed and a minimum combined scored has to be achieved to get the label</p> <p>(in addition to fulfilling all obligatory requirements)</p>	<p>Ecolabel License</p> <p>All obligatory requirements fulfilled, and point scores achieved (for DK):</p> <ul style="list-style-type: none"> • Small house min. 16 points (out of 42 relevant) • Apartments min. 17 points (out of 44) • Educational buildings min. 15 points (out of 39 relevant) 	
DGNB-Villa	<p>Total performance index (sum of % of achieved vs available Criteria Indicator points multiplied by Criteria weight factors)</p>	<p>Certification</p> <p>Certification requires performance index ≥ 50</p> <p>A scorecard shows the performance index as a number, alongside 1-5 stars within each of three Qualities depending on their degree of fulfilment</p>	
TAIL	<p>Points are not summed The quality level of each parameter is obtained by calculating the interim rating from the levels obtained in different locations in a building. Quality levels for the 12 parameters: green for interim rating between 1 and 1.4; yellow between 1.5 and 2.4; orange between 2.5 and 3.4; and red between 3.5 and 4.</p>	<p>Rating</p> <p>The overall (integrated) quality level of the indoor environment is determined and indicated by a Roman numeral:</p> <p>I - high (desired) quality level, II - medium (refined) quality level, III - moderate (ordinary) quality level, IV - low (undesirable) quality level.</p>	
IEQ-Compass	<p>Overall score</p> <p>Three levels of weighting: The weighting between all criteria within a given parameter provides a parameter score. The four parameters in each area are weighted to obtain an overall area score. The overall IEQ score is obtained after weighting the four areas equally.</p>	<p>IEQ Label</p> <p>Letter rank (A-G) and colour code (dark green to dark red) from overall scores: A: $85\% \leq \text{score} \leq 100\%$; B: $75\% \leq \text{score} \leq 85\%$; C: $65\% \leq \text{score} \leq 75\%$; D: $55\% \leq \text{score} \leq 65\%$; E: $45\% \leq \text{score} \leq 55\%$; F: $35\% \leq \text{score} \leq 45\%$; G: $0\% \leq \text{score} \leq 35\%$</p>	<p>The combined letter rank (A-G) can only score max. two ranks above the lowest individual rank for the four main areas. E.g. to obtain the rank A, no main area can be below C (minimum score: 65%)</p>

Overall IE Weights

Table 5 lists the contribution of the indoor environment to the total assessment within each scheme. First, the category under which indoor environment is considered is named, and its contribution is listed. However, content unrelated to IE may be included in this category, and IE-relevant content may be placed in other categories. Therefore, we provide a corrected contribution of indoor environment to the overall scheme, in which we consider these deviations and include all IE-related parameters. Thus, the corrected IE content weights in Table 5 address that some of the broader certifications consider IE performance only as a modest part of their overall certification scheme. Therefore, there is no guarantee that a building certified within one of these schemes has a good IE performance, as these areas could be down-prioritised.

In HQM, indoor environmental performance is reflected in the "My Well-being" score. Using all the IE-related parameters in the scheme (indoor pollutants, daylight, noise sources, sound insulation, temperature, ventilation, environmental impact of materials, drying space, smart control and commissioning of HVAC systems), the contribution to "MyWellbeing" score is 30%.

In Nordic Swan, indoor environment is covered by the "Indoor Environment" section by 6 "O" (Obligatory) issues. This section's share of the total assessment is 14%. After correcting the actual indoor environmental content in the whole scheme, including requirements about chemical content in materials and products, the overall contribution is 24%.

In DGNB-Villa, indoor environment is covered by the "Social Quality" section. This section's share of the total assessment is 30%, but also encompasses topics such as architecture, functionality and design for all. Using only the IE-related topics of that section (Air 8% (ventilation, indoor pollutants, temperature), Sound 5% (noise sources, sound insulation), and Light 5% (daylight)), they make up 18% of the total assessment. In addition, 2.5% points are added from an indicator in the economy section, "operational efficiency" (which makes up one-quarter of the points for ECONOMY 1). The criteria for operational efficiency awards points for supplying occupants with a user manual on optimising indoor environmental conditions during everyday use. Another section that could impact the final IE performance is related to healthy materials in the environmental section of the scheme. However, the manual states that these considerations are primarily to ensure a healthy work environment during construction and to reduce the amount of environmentally harmful substances in the building materials for recycling and waste management purposes. Material emissions are covered directly through air quality measurements in the Air category.

TAIL and IEQCompass cover only the indoor environment, and the contribution to the overall rating in these schemes is thus 100%.

Table 5 Contribution of indoor environment to the overall scheme. The contribution of exclusively IE-related parameters is shown

Certification	Main IE category	Corrected IE content weights
HQM	My Well-being	30%
Nordic Swan	Indoor environment	24%
DGNB-Villa	Social Quality	20.5%
TAIL	IE only	100%
IEQ-Compass	IE only	100%

Relative Weights for the Main IE Areas

Table 6 lists the relative contribution of each main IE area (thermal, acoustic, visual and IAQ) to the total contribution from indoor environment within each scheme. The relative weights are calculated based on either sub-category weights, the sum of points assigned within a category compared to other categories, or a simple count of the number of assessed criteria within the areas. All criteria assessed by the individual certifications are categorised into the four main IE areas whenever possible.

HQM

In HQM, the IE performance is indicated as part of the key area called "My Well-being". My Well-being counts up to 283.5 points (30% of the overall scheme), of which 68 are for IE issues. The relative weights have been identified by counting the number of available points for each main IE area as follows: Thermal (17), IAQ (25), Visual (13), Acoustic (13), and dividing them by the total number of points for IE issues (68).

Nordic Swan

The Obligatory "O" requirements are mandatory and do not provide any points as all of them must be fulfilled to receive the Nordic Swan certification (see the section Prerequisites below). Only the Points "P" criteria offer points, but within IE performance, they only exist for "Noise environment" and "Exterior solar protections". These additional "P" criteria are considered extra points to reward some specific choices in the design. Therefore, it would not be representative or accurate to provide a pie chart for Nordic Swan based on the limited availability of these 'extra points'.

TAIL

No weighting of the four components has been proposed. The four aspects of IEQ are treated as equally important. If one component is of poor quality, this is assumed to affect the overall quality of the indoor environment. The overall indoor environmental quality of a building is determined according to the lowest quality level among the four components. No points or weights are applied in the scheme; thus, the relative weights listed below are only informative of the relative content distribution. The content distribution reflects the number of parameters evaluated within each category.

DGNB VILLA

The DGNB Villa scheme lists overall criteria weights for sound (5%), daylight (5%) and air (8%). Thermal performance is included as part of the air criteria labelled as temperature. The weight from the air criteria is split into contributions from IAQ and Thermal parameters by counting the maximum possible points awarded in each category. The resulting weights are IAQ = 5.2% (from up to 157,5 points), and Thermal = 2.8% (from up to 85 points). The relative weights plotted in Table 6 are the individual contributions in %: Thermal (2.8%), IAQ (5.2%), Visual (5%), and Acoustic (5%), divided by the number of per cent points available for all four main IE areas combined (18%).

Note that the indicator for 'operational efficiency', which awards points for an IE user manual, is not included here, as it falls outside the four areas.

IEQ-Compass

All four IE areas are weighted equally, emphasising that priority needs to be put on all areas. However, each main area is evaluated through several weighted parameters, further assessed through one to six weighted descriptive criteria.

From the relative IE area weights listed in Table 6, it is clear that IAQ has a higher priority than the other areas in all schemes (except Nordic Swan and IEQCompass, which are irrelevant in the comparison). HQM puts most emphasis on IAQ and slightly less on Visual IE and Acoustic IE. DGNB Villa has a lower priority for Thermal IE, while the rest are almost identical. TAIL has a predominant focus on IAQ as two-thirds of the indicators measured are IAQ-related.

Table 6 Relative IE topic contributions for each certification and an average value in italics

Certification	Thermal	IAQ	Visual	Acoustic
HQM	25	37	19	19
Nordic Swan	N/A	N/A	N/A	N/A
DGNB-Villa	15	29	28	28
TAIL	8	67	17	8
IEQ-Compass	25	25	25	25
<i>Average</i>	<i>18,25</i>	<i>39,5</i>	<i>22,25</i>	<i>20</i>

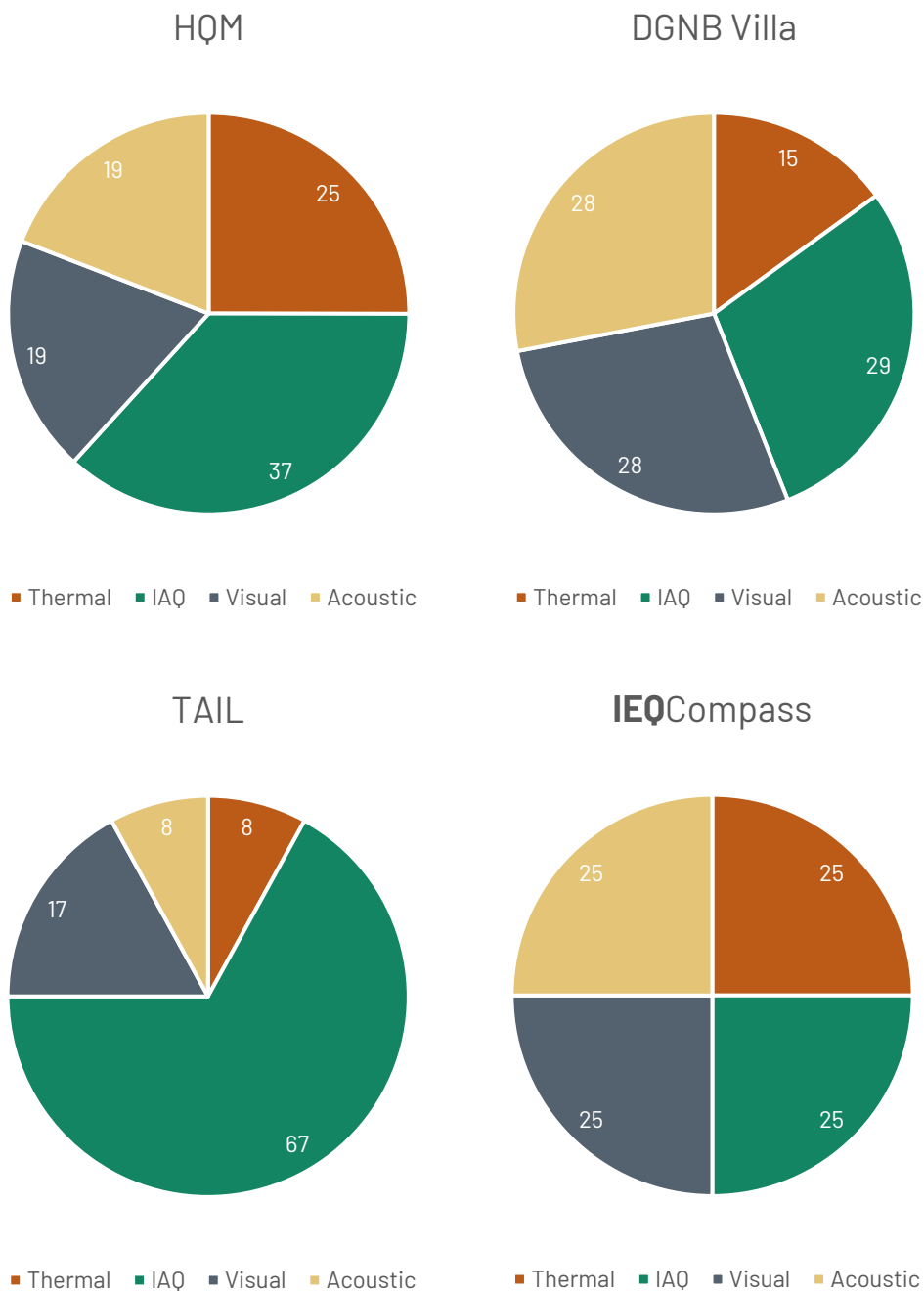


Figure 1. Pie charts of relative IE topic contributions for four certifications.

Prerequisites

Some certification schemes have a list of prerequisites that must be fulfilled to qualify for any level of certification. Since these criteria are mandatory, they are typically not scored or do not award points. These criteria are not counted as part of the overall IE weights or relative weights for the main IE Areas above.

HQM presents some mandatory requirements, which do not offer any points towards the final score but are essential to be fulfilled to gain a certificate under HQM ONE. The mandatory requirements have been set to ensure that all certified homes deliver a certain minimum quality. To ensure that the requirements have been selected to be more ambitious than the minimum regulation requirements.

Nordic Swan presents 41 obligatory criteria, which must be met to receive the certification. Many of the obligatory requirements for indoor environment are, however, part of the National Building Regulation requirements. As a result, the certification is not as demanding as it may seem at first glance.

DGNB Villa has no mandatory IE requirements as the scheme allows maximum flexibility when prioritising effort. Thus, although the overall performance index has to be between 50 and 100 points, there are no minimum quality or criteria level requirements. It is, therefore, possible to get certification without obtaining any points in one criterion (e.g. the daylight) or completely ignoring the entire Social Quality. However, the national Building Regulations have set minimum requirements for several IE criteria for new buildings, meaning that a minimum performance level is ensured indirectly, at least in the Danish context.

TAIL has no mandatory requirements, but measurement of all 12 IE parameters are compulsory, and the lowest performance decides the overall performance.

IEQCompass has no mandatory IE requirements, as the goal is not to introduce new, stricter requirements for buildings but to assess and label the potential performance of dwellings, including existing buildings. Through the transparency of IE performance, the idea is to motivate action in poorly performing buildings and reward a high level of performance through visibility. Note also that the indoor environmental quality label issued through the **IEQ**Compass will only be given to buildings that pass a quick assessment of the general conditions of the building.

Conclusions

This report summarises and compares five certification schemes focusing on the indoor environment of buildings, with a focus on residential buildings. The five schemes represent a range of approaches to certification. Their direct comparison is difficult because significant differences are inherent, given the vastly different points of departure in their design. Each scheme was developed to address a particular goal within a geographic area, building tradition, market and even culture. For example, Home Quality Mark has been developed in the United Kingdom specifically for new homes to improve the built quality, reduce the performance gap and provide a mark of quality for consumers, house builders, developers and housing providers. The Nordic Swan Ecolabel is an extension of the well-known Nordic product labelling for buildings. It covers the whole life cycle of the building, including the extraction and production of building materials, the construction process, the use phase, and the waste and recycling phase. It has been designed to promote circular economy, reduce climate impact, save resources and preserve biodiversity. DGNB is a total value sustainability assessment with a strong element of economic and social considerations. DGNB-Villa is an extension of the existing DGNB certification for single-family houses and has an increased focus on the indoor environment.

Thus, while some certifications purely focus on the indoor environment of buildings (TAIL, IEQCompass), others use a more holistic approach considering economic, social and well-being aspects, with the indoor environment taking only a relatively small share of the overall certification (20-30%). Additionally, while some schemes (e.g. IEQCompass) have been designed strictly to avoid field measurements, others rate the indoor environment during its everyday use strictly using measurements and observations (TAIL). Some of these schemes are new and are not yet fully established or have broad applicability, including non-residential buildings; others are adaptations of existing and recognised certification schemes for residential buildings. As a result, it is not surprising that there are differences in what the certifications cover regarding the included parameters, their weights and the relative contribution of the four main IEQ areas (thermal IE, acoustic IE, visual IE and IAQ) to the overall rating.

Given these differences, the five presented certifications should be perceived as complementary rather than competitive. When choosing one certification over another, any decision should consider the nature, applicability/usability, impact, relevance and cost associated with the various schemes. It is often the latter that becomes decisive. It is not possible to list the final costs for obtaining the various certificates (as it will be project- and market-specific), but Table 7 provide an overview of some factors that strongly influence the final costs. These include the methods used to evaluate the indoor environment (observations, measurements, calculations), the need for building visit, any associated fees, and the need for consultancy with various experts. The business model with which a certification scheme operates (e.g. the need for trained assessors) also impacts the associated expenses.

Table 7 may indirectly suggest that HQM, Nordic Swan and DGNB-Villa carry a more significant economic burden than the other two schemes. TAIL is a framework which has not yet been applied in practice, but it has a more focused scope than the broader certifications. IEQCompass is unique in being the the only scheme which does not require physical measurements. Also, all necessary calculations and simulations are automated and handled directly in the tool. IEQCompass has been designed to be on par with the much used and recognised energy certification schemes, both in extent, impact, required resources and economic burden, thus potentially making it one of the most attractive schemes for building owners and buyers. As the scheme only covers indoor environmental performance, it must be combined with other assessments to cover overall environmental performance.

The IEQCompass is also the most flexible certification of the five, as it is applicable for both new and existing buildings and design and renovation processes. It is currently developed for multifamily homes in Denmark but is adaptable for other types of buildings and regions. A more detailed evaluation of the IEQCompass' potential is described in the main project report.

Table 7 Predicted expenses associated with the five certification schemes

	HQM	Nordic Swan	DGNB-Villa	TAIL	IEQ-Compass
Assessor qualifications	Yes (HQM assessor)	Yes (architect, technical consultant or similar)	Yes (DGNB-consultant)	No	Yes (IK-consultant course)
Checklists	Yes	Yes	Yes	Yes	Yes
Evaluation method	Yes (daylight and thermal comfort)	Yes (daylight, thermal comfort, energy with dynamic simulation, e.g. IDA ICE, VIP+ or BV2)	Yes (some done by tools - others handled individually, summer comfort in Be20/BSim/IDA-ICE/IESVE)	Yes (daylight factor)	Yes (automatically performed by built-in tools based on checklists and simple input data)
Measurements	Yes (VOCs, acoustics, local air quality, energy and water)	Yes	Yes (various measurements of IAQ and acoustics)	Yes (10 parameters)	No
Need for building visit	Yes	Yes	Yes	Yes	Yes
Fee	Yes	Yes	Yes	No	Yes
Consultancy expenses	Yes	Yes	Yes	Yes	Yes

Screening of IEQ content in five building certifications

This report is part of the deliverables within the project PRJ-2021-00199 funded by Realdania. The project is a collaboration between Danish universities, real estate companies and building materials manufacturing companies to lay the foundation for adapting the recently developed **IEQCompass** to single-family houses. The **IEQCompass** is a certification scheme that evaluates the potential of a building to provide a comfortable and healthy indoor environment. It was initially developed for multifamily social housing, and its adaptation, relevance and feasibility within other building types will be evaluated.

Content of this report

- This report compares the existing version of the **IEQCompass** scheme with other certification programs focusing on the indoor environment of residential buildings.
- The investigated certifications were selected among the large number of existing building certification schemes considering the role of indoor environmental quality in the overall certification, the applicability for dwellings (mainly single-family homes) and the relevance for the Danish context.
- The report compares the indoor environmental quality aspect, structure, content and weighting of five selected certification schemes.

This project is funded by Realdania.