

BIM and Energy Simulation Enables the Use of Life Time Indicators during the Design

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Profile of Author:

Maija Virta has over 20 years of experience in construction and HVAC-industry and her main topic of interest has been sustainable building policies and technologies. She was the CEO of Green Building Council Finland 2010-2012 and she has been active in European level by contributing in REHVA, the Federation of European HVAC-associations. Maija Virta is a Fellow of REHVA and a member of ASHRAE. She has published over 30 technical papers in international conferences and she has been lecturing in ASHRAE Learning Institute as well as seminars organized by ISHRAE and ASHRAE Indian chapter. She is the main author of two REHVA guidebooks: "Chilled Beam Applications" (2005), and "HVAC in Sustainable Office Buildings – A bridge between owners and engineers" (2012). Maija Virta contributed in writing award-winning book "Sick Building Syndrome in public buildings and workplaces" the article "Solving Indoor Environmental Problems: What Can Be Found Out through Individual Measurements? ".

1. Life time indicators of building's performance

The built environment is in the key role when reducing the greenhouse gas emissions in our societies. That is why we need measures and tools that lead to improved indoor environment quality, more efficient building performance and to real carbon emission reduction. Both the property owners and building professionals should commit to reduce carbon emissions also in voluntary basis. We need practices and tools that are cost effective and simple to use in any building or project. But in the other hand we need practices and measures that support the professional property owners to demonstrate the performance of their buildings in international property market.

Green Building Council Finland has focused on last two years to determine the key performance indicators (KPI) for sustainable buildings that ensure the sustainable operation over the life time. Both LEED and BREEAM certification tools have been used in Finland, but as they do not evaluate the actual performance of a building, it is important to set also other measures for construction projects and management of existing buildings.

The main focus has been finding KPIs that focus on the environmental, social and economic sustainability over the life time of building and are based on international standards. Data need to be collected and followed already in pre-design and design phases from planning documents and later from the building management system and building's users.

We recognized several user groups. The primary target has been to define KPIs for professional property owners and developers. They operate with large building stock and they have the knowhow and financial resources to invest on tools and consulting work. In apartment buildings the decision making power is often in the hands of apartment owners and therefore the process to measure KPIs need to be very cost effective and measures need to be understood by non-professionals. Same is valid with single-family house owners.

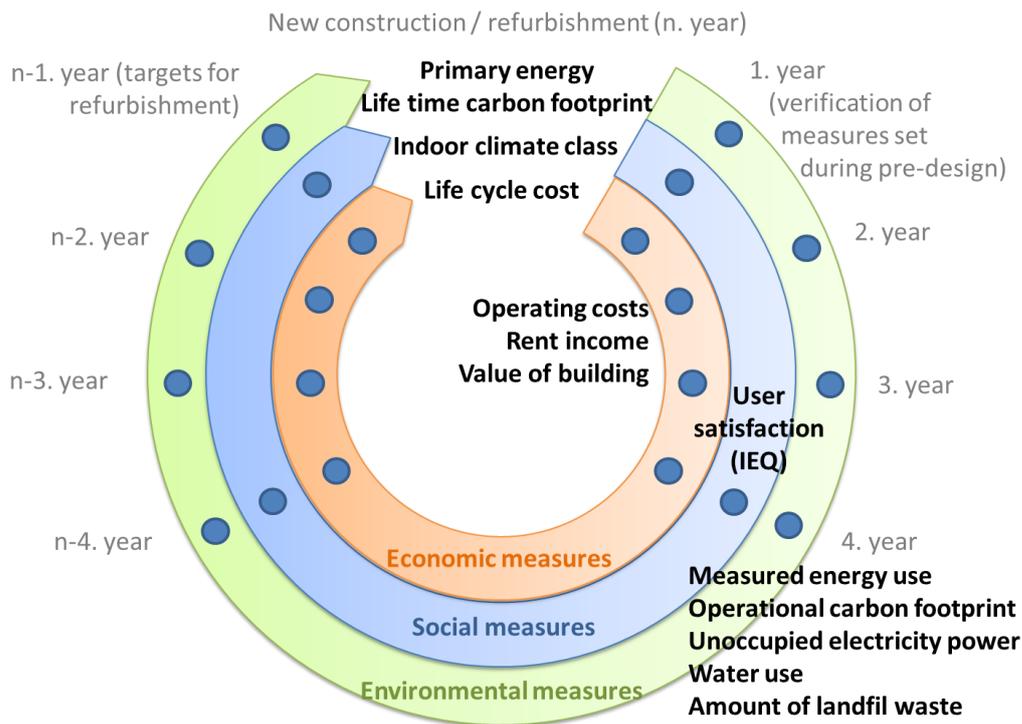


Figure 1. Property management measures and construction project measures shall be chosen based on sustainable life time. The same area of sustainability is measured using different KPIs during the project and life time management.

The objective is that performance evaluation becomes part of the normal design, maintenance and portfolio management. By following KPIs and making decisions accordingly, we can improve the user satisfaction and wellbeing; make sure that spaces are efficiently used; reduce the operation and maintenance costs; and reduce the environmental load.

The main focus has been finding indicators for Finnish buildings. But to make sure that they are supporting also the needs of international property business, they are based on international standards and practices. This way the Finnish property market can fulfill easier the requirements of international investors. It is also important that different evaluation and reporting systems use the same calculation specification as this way the extra work to specify same KPI with different specifications can be avoided. Most of the chosen indicators are based on CEN TC 350 standard package.

KPIs can be used for different purposes. One is to evaluate and manage the operation of a building over the years. This case the best benchmark values are the values of previous years. Second way is to compare building to other buildings with same purpose. This can be done in a property portfolio level or based on a national or international database. Unfortunately only few KPIs have a good database for general comparison; especially because the specification has not been uniform.

Sustainability evaluation needs to be based on the life time evaluation of building and its usage. Service life planning is the basis of all evaluations made in design phase. There are several areas to be considered:

- predicted service life of building and major components (defined by developer);
- usage of spaces and possible changes over life time;
- indoor environment quality in different usages;
- environmental impacts over life time (including deconstruction and re-use of materials);
- lifetime costs.

Target setting in the pre-design phase is very important. The same measures shall be followed over the life time of building, even the actual KPI and how it is specified may be different. Targets can be set for various issues, but in this project we choose the following areas: indoor environment quality, energy efficiency, carbon footprint and life cycle economy.

We recognized indicators in each area, which were then specified more detailed. There were three other areas we recognized important: waste water efficiency, waste management efficiency and abiotic resource depletion. Specification of these indicators will be done in the second phase of the project. We also did not focus on traditional financial measures like operating cost or rent income.

Table 1. Selected key performance indicators.

	Project phase		Operation phase	
Indoor environment	Indoor environment class (EN 15251)	A/B/C	User satisfaction (thermal comfort, IAQ, lighting and acoustics separately)	%
Carbon footprint	Life time carbon footprint (EN 15978)	kgCO ₂ /m ²	Operational carbon footprint (GHG protocol)	kgCO ₂ /m ² ,a
Energy	Calculated primary energy consumption (EN 15217)	kWh/m ² ,a	Measured energy use (electricity, heating, and district cooling separately)	kWh/m ² ,a
			Unoccupied electricity power	W/m ²
Economy	Life cycle cost (EN 15643-4)	€/m ²	Value of building (discounted cash flow DCF)	€/m ²

2. Use of life time indicators requires new tools

Collection and storage of information need to be planned already in design phase. This may require e.g. more measurement equipment to be installed in the building. Building Information Modeling (BIM) system helps to follow the targets both in design and in operation face, but it is also a good tool for data storing and management over life time.

During the design phase the values of indicators can be collected from different performance analysis e.g. energy and indoor conditions simulations. Quantity data can be collected e.g. from building information modeling (BIM).

Building information modeling (BIM) is the process of generating and managing building data during its life cycle. Typically it uses 3D, real-time, dynamic building modeling software. It eliminates many clashes usually found during the construction phase since they can be identified already during the design. Also, during construction the BIM model will be automatically updated with any changes.

Building information modeling (BIM) can be used to demonstrate the entire building life cycle, including the processes of construction and facility operation. Quantities and shared properties of materials can be extracted easily.

If all performance related data is saved and continuously updated in the BIM model throughout the life time of the building, different performance and sustainability analysis are easy to make during operation years. The BIM model provides up to date data for e.g. technical due diligence (DD) process, which are made much faster and with less costs. The BIM-model also provides information required for Life Cycle Cost Analysis (LCCA) and Life Cycle Assessment (LCA) of the building, as well as data for calculating performance indicators. In addition, this information can be easily assessed by a third party and afterwards integrated case by case into the valuation process.

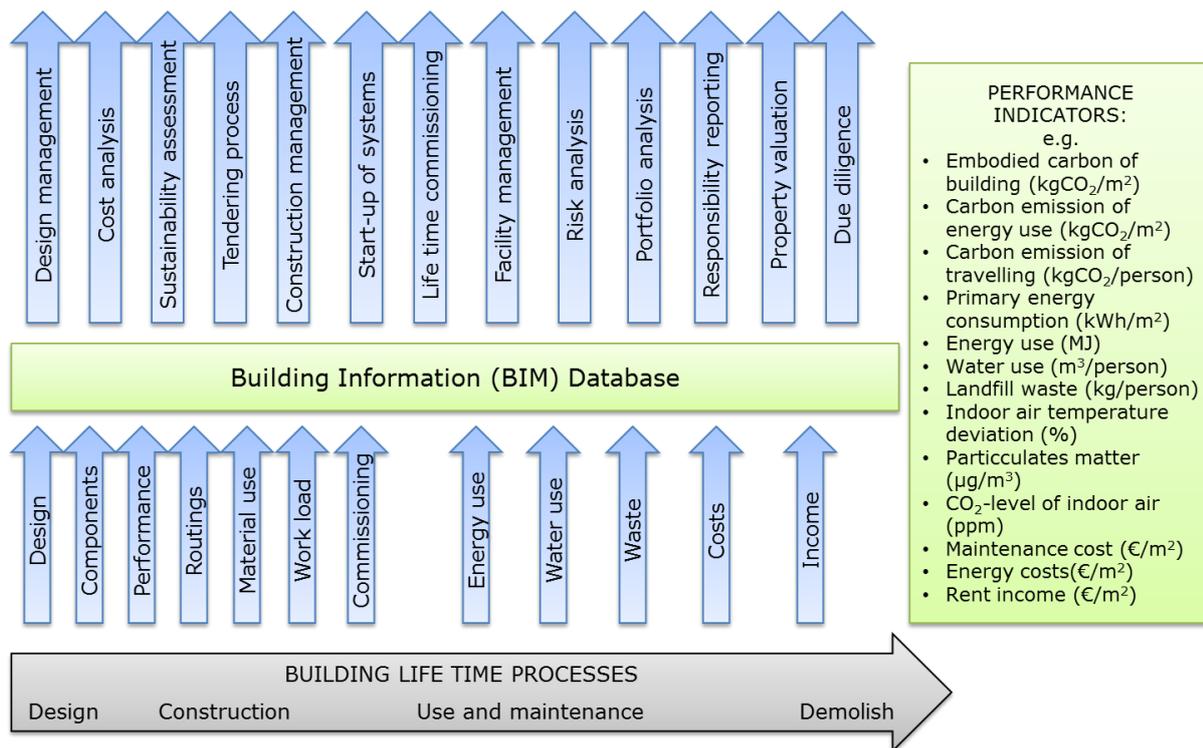


Figure 2. Building's performance data should be collected throughout the life time of the building i.e. product manufacturing, design, construction, commissioning, facility management and demolishing. Once the data is stored in one place, management and different analysis are easy and fast to make and performance indicators are continuously up-to-date.

Especially "Life time carbon footprint" and "Life cycle cost" indicators require lots of data and calculation work. That is why they have not been calculated as part of normal design process and neither are they part of the LEED design. But the new tools, like BIM and energy simulation tools, enables the efficient data collection and processing. Therefore the decisions during the design process can be made based on the life time evaluation of building.

To collect and manage all information needed, the BIM system makes it easier, faster and more cost efficient. 3D architectural CAD-model includes all volume and quantity data of building materials and components. 3D CAD-model is also transferred to IFC-database. This is an international standard to transfer the information between different simulation tools, like energy simulation. Once the first design of building is available and all performance and life cycle cost analysis are made, the data is stored to BIM-system and first set of performance indicators can be calculated.

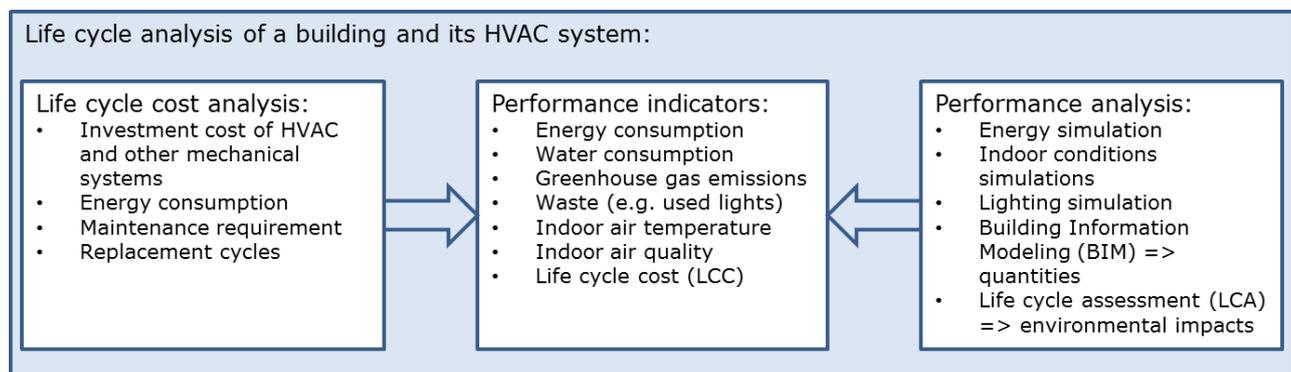


Figure 3. Performance indicators can be calculated in design phase after life cycle cost and performance analysis are made.

Example of a performance indicator: life time carbon footprint of building

Life time carbon footprint of building describes the environmental impact of building, and is calculated during the design process. It can be used for example to compare alternative designs of building and mechanical systems. It takes into account the carbon emissions from cradle to grave:

- embodied carbon of construction materials;
- construction work and transportation of materials;
- calculated life time energy use and maintenance of building;
- end of life: deconstruction, reuse, recycling and waste.

Life time carbon footprint requires the quantity (m, m², m³ or kg) data of foundations, supporting structures, floors, façade and partitioning walls, windows, doors and roof. Each material is then multiplied with the corresponding carbon emission data presented in Environmental Product Declaration (EPD) of each material. EPDs are created by product and material manufacturers and they will be an important part of future product data. Or alternatively, the generic EPDs of each material can be used during the design phase, when material and component selections are not yet final. There are many data bases in the world having the generic data of environmental impacts of products.

Top of that the carbon footprint of all transportation and construction works needs to be added as well as the carbon emissions during the life time operation (energy, refrigerant leakages, repairs, maintenance, and water management).

Also the deconstruction work, reuse of materials as well as management and transportation of waste in the end of life need to be planned and included into the calculation. Life cycle costing requires also the cost data of all materials and work. In practice BIM is the tool to collect and manage all that data during the different phases of design and construction processes as well as over the life time operation.

Life time energy use is still 70-90% of building's life time carbon emissions and therefore it needs to be evaluated separately. The building's energy efficiency and renewable means of energy supply are important in meeting future carbon reduction targets and future building regulations. But it also is important what type of energy is purchased from the national grid. The amount of energy used in buildings depends on the climate, the building type, the HVAC-systems design, selected products as well as on the tenant's activities.

Dynamic energy simulation is necessary when optimizing the building, designing technical systems and selecting the HVAC-components. Oversized system and components may unnecessarily increase the energy use of building over life time. Correct design also improves the cost efficiency as all the components in cooling and ventilation system are selected based on the real need.

3. Accurate design requires precise product information

Life time indicators are used to produce better designs. But more detailed and accurate the design process is, more precise product data is required during the design phase.

Usually the product manufacturers are using the product performance data measured in their own laboratories. Measurements are typically made based on international testing standards. In Europe the measurements are based on ISO or CEN standards, in USA based on ISO or ASHRAE standards and in India there will be soon available also ISHRAE-RAMA standards, like the chiller testing standard.

Product performance data is used to make a design of a building. As the energy efficiency has such an important role in performance evaluation nowadays, it is very important that

designers are using energy efficient products and that products' performance data is precise. If the performance data is correct, the design can be made correctly and no unnecessary safety margins need to be added. This means savings in investment costs as products are smaller in size. System will also perform more efficiently, as each product performs longer period of time in optimum performance area. In a typical design the product performance is optimized to design conditions. But in oversized systems the product operation hardly ever meets the design conditions but operates in partial load conditions. Many products consume more energy in non-optimum conditions.

Environmental information of products and building materials life cycle is also needed. Today Environmental Product Declaration is mainly voluntary information; however in France it is already required by law. But more clients are calculation the life cycle carbon a footprint of their buildings and therefore it is becoming a necessary data in major building projects.

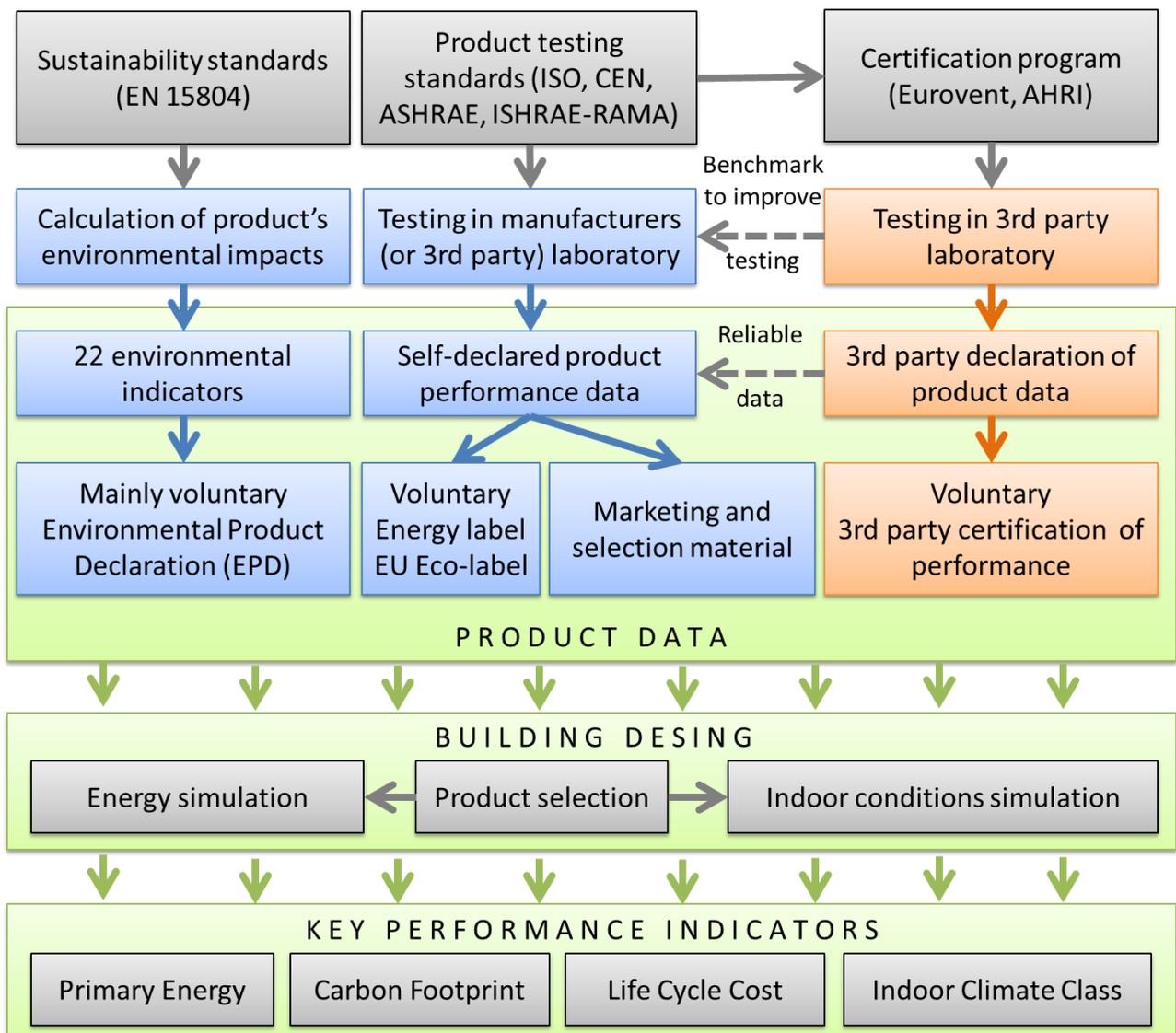


Figure 4. Accurate and more detailed product data is required, when designing buildings in the future and calculating the key performance indicators during the design.

3rd party certification to get accurate product data

The 3rd party certification of product data is a good process to ensure the accurate data of product and avoid the need of unnecessary safety margins. The certification mark ensures that the products have been submitted to independent checking. This mark guarantees designers, installers and end users that products marketed by a company have been accurately rated. It also ensures a healthy and solid competition on a market open to all manufacturers.

The purpose of Certification Programmes is to create a common set of criteria for the rating of products. Through specification of certified products, the engineer's tasks become easier, since there is no need to carry out detailed comparison and performance qualification testing.

When a manufacturer participates in a certification programme, he has to present its list of models or model ranges together with their performance data. The files are evaluated by Certification Company and a predefined number of units are selected for testing by independent laboratories.

If results comply with the relevant standards, models or ranges are listed in the online Directory. Models are subject to regular random testing to verify compliance with catalogue data. The scope of each certification programme must be clearly defined. All products of the relevant certification programme, manufactured or sold by a participant under the defined scope, must be certified.

Only products that may be tested in an independent laboratory shall be included into the scope of a programme. For some products the selection software is certified and the smallest size of the range must be such that the testing in an independent laboratory is possible.

The 3rd party certification program can also improve the testing processes of a manufacturer as they get benchmark values of product performance from independent laboratory. This improves also the product data of other product groups, which are not part of the certification program.

The scope of each certification program must be clearly defined. All products of the relevant certification program, manufactured or sold by a participant under the defined scope, must be certified. When applicable, the "certify-all" procedure means at least "all products under the defined scope presented on the European market", but larger applications may be implemented.

There is clear evidence in markets that product performance data has improved after 2002, when new European regulation for performance labeling was decided.

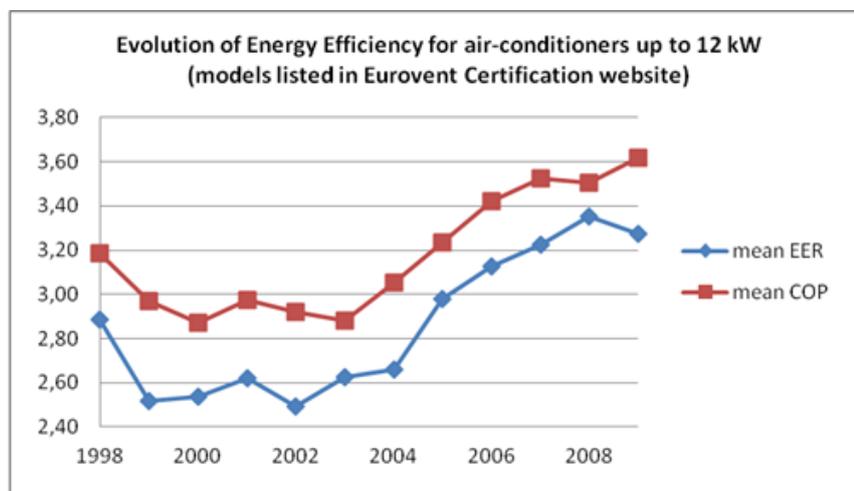


Figure 5. Diagram presents an average performance of AC equipment less than 12 KW in cooling (blue line) and in heating (red line) before and after the new performance labeling regulation 2002. (Eurovent-certified, 20+ manufacturers, more than 1500 product references)

The improvement in product data can be due to several reasons. Firstly the poorly performing products are withdrawn from the market and therefore the average performance improves. Secondly manufacturers get "a tool" to promote better performing products as purchasers and users becomes more aware of the necessity of well performing products. And of course the energy labeling and certification schemes encourages manufacturers to develop better products.

The third party certification is adding value to entire business chain and helps also government to achieve the carbon reduction and energy saving targets. Authorities can follow the trends based on the third party sampling and make data really comparable before and after regulation change.

Environmental data will be required from HVAC-products in Europe

A new area of product information is the environmental impact of product. The European standard EN 15804 defines 22 environmental indicators for products and materials, standard methodology to define them and a reporting structure. This standard report is called Environmental Product Declaration. The standardized indicators are following:

1. Global warming potential (GWP)
2. Ozone depletion potential
3. Acidification for soil and water
4. Eutrophication
5. Photochemical ozone creation
6. Depletion of abiotic resources elements
7. Depletion of abiotic resources-fossil fuels
8. Use of renewable primary energy excluding renewable primary energy resources used as raw materials
9. Use of renewable primary energy resources used as raw materials
10. Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials
11. Use of non-renewable primary energy resources used as raw materials
12. Use of secondary material
13. Use of renewable secondary fuels
14. Use of non-renewable secondary fuels
15. Use of net fresh water
16. Hazardous waste disposed
17. Non-hazardous waste disposed
18. Radioactive waste disposed
19. Components for re-use
20. Materials for recycling
21. Materials for energy recovery
22. Exported energy

An EPD communicates verifiable, accurate, non-misleading environmental information for products and their applications, thereby supporting scientifically based, fair choices and stimulating the potential for market driven continuous environmental improvement. EN 15804 standard defines the parameters to be declared and the way in which they are collated and reported. It describes which stages of a product's life cycle are considered in the EPD and which processes are to be included in the life cycle stages. Standard also defines rules for the development of scenarios and includes the rules for calculating the Life Cycle Inventory and the Life Cycle Impact Assessment underlying the EPD, including the specification of the data quality to be applied. It includes the rules for reporting predetermined, environmental and health information, that is not covered by LCA for a product, construction process and construction service where necessary. And it defines the conditions under which construction products can be compared based on the information provided by EPD.