FINAL REPORT

1 FINAL PUBLISHABLE SUMMARY REPORT

1.1 Executive summary

PERFECTION is a European FP7 Coordination Action for Comfort, Health and Safety of the Indoor Environment which started in the beginning of 2009 and lasted for 3 years until the end of December 2011. The project was introduced in the FP7-ENV 2007-1 and was coordinated by the Belgian Building Research Institute. It involved 10 other participants (VTT, Apintech, CTU, Armines, Kornadt, ICTAF, SiTI, TUE, ASM and BRE).

The goal of this FP7 coordination action was to help enable the application of new designs and technologies that improve the impact of the indoor built environment on health, comfort, feeling of safety and positive stimulation. To reach this objective an indicator framework as well as assessment tools based upon the framework had to be developed.

At the start of the project, a European-wide **network of experts and stakeholders** has been set up, enabling an extensive knowledge of European and national practices related to the indoor environment. With their help, **a database** holding standards, regulations, policies and research activities from 27 countries has been created. This inventory served as a solid basis:
- for structuring the making of a Compendium for Health & Comfort and Accessibility & Safety Indicators;
- to make the analysis for indoor performance indicators still to be developed;

Collection of the information inputs was performed by an extensive survey among all the PERFECTION partners and the whole expert network associated to PERFECTION.

Two separate and extensive **review reports on indicators** have been prepared. The first one focuses on health and comfort related issues, the second on (feeling of) safety, security, positive stimulation and accessibility indicators. The reports offer a detailed overview and state-of-the-art with regard to these important societal properties.

Both reviews have served as a basis for the development of a generic framework for core building performance indicators and an indicator toolbox. The developed indicator framework, which is called the **PERFECTION Key Indoor Performance Indicators (KIPI) framework**, is structured in a hierarchical way. The KIPI indicators are divided into four main categories and 8 sub-categories:
- Health and Comfort
- Safety and Security
- Usability and Positive Stimulation
- Adaptability and Serviceability

Each sub-category is composed by performance indicators that are further characterized by specific technical indicators. The PERFECTION KIPI framework may be used for the assessment of the indoor performance of buildings. For each indicator, simple and detailed assessment methods have been defined, and this both for the design phase and for the operational one.

In order to validate and to test the framework, an **Excel-based toolbox** has been developed in parallel with the generic framework. The framework and toolbox were essential preparatory steps towards the **building decision support tool** developed by PERFECTION. The aim of this

tool is to be able to characterize indoor performances, with regard to health, comfort, security, safety and other issues that could improve the well-being of people living, working or visiting a building. The PERFECTION building evaluation tool can be accessed on http://www.indoorperformance.net. It offers users the possibility to evaluate projects and to demonstrate them as showcases. Together with the Building DSS **a promotional tool on indoor environment products and technologies** to be evaluated against a subset of PERFECTION indicators has been developed. The promotional tool allows producers to communicate about their products and allows users to search for them. It is accessible at http://products.indoorperformance.net.

Finally, PERFECTION has prepared policy recommendations, in the form of 2 detailed preparatory deliverables, a **PERFECTION policy support paper** and a **PERFECTION IP indicator roadmap**. The policy work has been summarized in a concise policy brief and will be published on the official perfection website (on http://www.ca-perfection.eu).

1.2 Summary description of project context and objectives

Context

In the former years, several approaches have been developed in the EU as regards the assessment of the indoor environment and building sustainability and the establishment of respective indicators. It is exactly because of the many activities and elaborations in the area of indoor environment and building sustainability that the potential of a coordinated activity is maximized. Learning from each other and setting a common agenda and a common roadmap constitute the obvious reasoning for this.

There are numerous published indicators within the PERFECTION scope available. The standardization work by e.g. ASHRAE, ASTM, CEN (TC156W1, TC264WG7, TC350, TC351), EC (CPD 89/106), EOTA (PT9), ISO (16000/TC146SC6, 16814/TC205) and WHO, without even mentioning all, gives extensive references on indoor health related indicators. In addition, CIB has produced an internationally accepted Compendium of Building Performance framework including the categories of safety, comfort, health & hygiene, service life, and usability and maintainability. CIB has also an active Working Commission W077 on Indoor climate and its large EC funded Performance Based Building Thematic Network (2001-2005) included a domain for Indoor Environment (led by the respective task leader in PERFECTION).

A number of the PERFECTION partners have been involved in the compilation of different performance and sustainability indicator systems in the immediate past (e.g. CRISP, ECOServe, Hope). However, the lack of a strong contextual element was what the PERFECTION consortium saw as one of the drawbacks in assessment methodologies, and related metrics and indicators.

The indicator framework developed by PERFECTION positions not only health, comfort, safety and accessibility indicators. It also includes other important indoor performance indicators that touch on sustainability aspects, such as adaptability or usability in a form that designers can communicate to clients. In this perspective, the goal of Perfection was to take into account the results of the LEnSE, ManuBuild, PeBBu and TISSUE projects to further detail or reformulate the core performance indicators and actively engage the end user considerations.

In addition, the project seeked to emphasize the end-user role, making the approaches more user-oriented. At the end, the uptake of any technology or policy will indeed depend primarily on providing the European user with a clear metric of its impact on the indoor performance. The less ambiguous the impact of a new technology, the faster the awareness creation and the higher the penetration of the technology in the building domain will be. Along the same line of thought, policies may also be considered. A fast evaluation of the impact of any (voluntary) policy would support its social basis and fast adoption.

Objectives

The aim of the PERFECTION coordination action was to help enable the application of new building design and technologies that improve the impact of the indoor built environment on health, comfort, feeling of safety and positive stimulation. In order to reach this objective, the project objectives were defined as follows:
- a repository of good indoor performance indicators for health, comfort and safety
- a repository of state of the art environmental technologies that appear to have the potential for an important impact on the indoor performance and sustainability of the built domain
- an interoperable framework for performance indicators qualifying the indoor environment, allowing the successful life cycle management of sustainable buildings and stimulating the exploitation of appropriate technologies
- a decision support tool for different user groups applicable to different building types findings from selected pilot cases of the use of the indicators framework and the relevant indoor performance indicators
- recommendations on policies and the future research agenda: a roadmap including incentives and barriers for the application of building design and technologies to improve the quality of indoor environments knowledge and good practices on performance indicators for health, comfort and safety in the indoor environment.
- a wide dissemination of findings through an extensive expert network and the organisation of a series of events.

Creating an indicator framework was merely seen as the first building step of the PERFECTION coordination action. An important work package focused on the use of indicators and the way they could stimulate the development and the uptake of new designs and technologies. In that regard the above mentioned objective of developing a PERFECTION user decision support tool must be seen. In the end this tool was comprising 2 modules:
- An evaluation and assessment module on the level of buildings with metrics and benchmarks defined in the indicator framework.
- A promotional module where product and technology solutions related to the PERFECTION scope and allowing to achieve an improved building enhancement mark can be publicized against a defined template.

Finally PERFECTION had also a series of policy related objectives. As a matter of fact, PERFECTION aimed:
- To formulate a set of recommendations to the EC and the Member States with regard to incentives and barriers to new designs and technologies.
- To formulate a set of recommendations to the EC, the Member States and Industry with regard to the needs and priorities of the future.
- To deliver a Policy Support Paper with regard to the CPD, EPBD, EEHAP, standards and regulations.

- To describe an Indoor Core Performance Indicator Roadmap that describes various development paths towards the desired future state taken cognizance of different time frames, technology maturity and relevant policy action plans (barriers and incentives).

PERFECTION and Dissemination Activities

The project was carried out at an EU scale and the project results reached nearly all EU countries. More than 30 experts from over 27 countries were carefully selected to be part of the PERFECTION CES team to ensure the necessary depth and width. The CES-network consisted of experts from various domains linked to the ENV.3.1.5.2 call; such as indoor health issues, acoustics, universal design, performance metrics and tools, sustainable design and construction, etc. Clear project yardsticks were the following:

- Engaging in the project roll-out partners or subcontractors from all EU-27 countries and securing a networking effect, extending well beyond the project lifetime. Next to 11 key partners, a great number of so called network partners representing industry from SMEs to LSEs, academia and research, from all over the EU and the accession countries, should actively contribute to the common goal.
- Organizing 5 events all across Europe (North, East, South-East, South-West, Central), two with a policy focus, two with a research focus and one business focused. A sixth smaller-scale event had to be organized for EC officers and should focus on EC policies in the areas of environment, enterprise, transport and energy, employment, social affairs and equal opportunities.

In the context of dissemination a series of publications and communications have been prepared, incl. 2 newsletters, a flyer, videos, user manuals, and deliverable reports.

1.3 Description of the main S&T results/foregrounds

WORK PACKAGE 1: INDOOR INDICATORS & FRAMEWORK

Inventory of Standards, regulations, technologies, research activities and policies (D1.1 & D1.2)

A summary of existing standards, regulations, technologies, recent research efforts and policies related to the Indoor environment of buildings was the objective of the two first tasks of the project. In order to reach this goal, an EU-wide survey has been organized. Through this survey, a total of 313 complete inputs was collected. The structure of the inputs is as follows: 114 standards; 95 regulations; 21 technologies; 55 research activities; 28 policies. The survey inputs were directly linked to 91 relevant indicators of the indoor environment and the database enabled a search of the items by these indicators. The technologies listed in this deliverable served as a basis to the product database which has been later enriched by other products.

Health, comfort, safety, accessibility and positive stimulation indicators (D1.3 &D1.4)

In order to build a generic framework for the indoor environment, the project team has started by producing an extensive list of indicators concerning health, comfort, safety, accessibility and positive stimulation.

In PERFECTION's Task 1.3 current performance indicators, standards, regulations, guidelines, research activities and policies used in design and construction of the built environment,

focusing on performance indicators for health and comfort (indoor environmental quality), have been investigated. The objective was to present a review of health and comfort indicators for indoor environment in buildings. The outcome of Task 1.3 is presented in the associated deliverable report. It comprises the following results:

- First of all, the earlier work, mainly within EU-projects, on performance based building and performance indicators for the indoor environment has been analyzed. The Performance Based Building (PBB) concept and definitions of terms applied within the context have been evaluated.

- Second, a general definition of a (core) performance indicator was defined. It has been demonstrated that a core performance indicator can be described by a set of indicators or parameters. Each indicator or parameter can be assessed qualitatively or quantitatively.

- Third, specific health and comfort performance indicators related to the indoor environment have been reviewed. An analysis of existing indicators has been performed. Performance indicators for the five key indoor performance indicators (acoustic comfort, visual comfort, indoor air quality, quality of drinking water and water re-use, and thermal comfort) have been presented. For each performance indicator, specific indicators, parameters, and informative target values are documented.

From this list of available performance indicators, a selection has been recommended for the application in an indicator framework for the assessment and evaluation of sustainable buildings. Following indicators were recommended:

Indoor air quality:
- Effective temperature
- Effective ventilation
- Combustion sources/infiltration
- Odour acceptance
- Particulate matter

Water quality:
- Drinking water quality
- Rain/re-use water quality

Thermal comfort:
- Operative temperature

Visual comfort:
- Illuminance
- Daylight factor

Acoustic comfort:
- Background noise level
- Reverberation time

Task 1.3 demonstrated that the level of detail on which the information for the assessment of a building is available, is the main issue that influences the complexity of the indicator framework. Often, a specific indicator can be assessed on a global level, based on a qualitative and more subjective evaluation of the performance indicators, or a more detailed level, based on a quantitative and objective evaluation. While questionnaires and checklists may be suitable assessment methods for the first approach, detailed measurement of the performance indicators and corresponding parameters is recommended for a second more thorough approach. Focusing on the development of an indicator framework it is recommended to apply such a distinction (global vs. detailed) within the project.

Task 1.4 covered an area which is less studied than the health and comfort one, but which is nevertheless important from an economic, social and even environmental point of view. Interesting to note is that the study demonstrated that this area clearly offers opportunities for innovation and technological development. The review of task 1.4 has listed indicators for two levels of evaluation: high level indicators (abstract) and basic detailed indicators. It covers four main topics:

- Accessibility
- Safety
- Security
- Positive Stimulation

For the first topic, the indicators related to accessibility were split into five sections:

- Approach to the Building
- Entrance to the building
- Movement inside the building
- Facilities in the building.
- Communication in buildings.

For each of these sections, a list of basic design indicators were described (ramp slope, door width, etc...).

For the second and the third topics, the review covered a wide range of topics and related indicators. The following safety and security domains were covered by the report: structural safety, mechanical safety (Glazing, Slips trips and falls, collision or entrapment, falling objects), fire safety, food safety, flood safety, electro-magnetic safety, cyber security, privacy and security of users and goods.

Finally, the deliverable introduced the concept of positive stimulation and proposed a list of indicators related to positive stimulation in different kind of buildings (offices, stores, hospitals, dwellings).

The PERFECTION KIPI Framework (D1.5 & 1.6)

The Key Indoor Performance Indicator (KIPI) framework of PERFECTION is the common result of Task 1.5 which produced the first version of the framework, and of Task 1.6 where the first version was improved.

The final KIPI Framework contains 4 main categories, each composed of 2 subcategories, and 31 performance indicators. The KIPI Framework is presented in detail in Fig 1. The four main categories of the KIPI Framework are:

- **Health and Comfort**, dealing with items such as mould growth risk, ventilation/CO2, combustion sources/infiltration, particulate matter, drinking water quality, operative temperature/PPD, illuminance, daylight factor, background noise level and reverberation time.
- **Safety and Security**, covering safety in use, feeling of safety, meeting current regulation, Building type specific safety issues, personal and material security, security of information and reliability in exceptional cases.
- **Usability and Positive Stimulation**, with as indicators access to and in the building, wayfinding, adjustability, view to outside, privacy, feelings and sensations and availability and quality of recreational spaces.
- **Adaptability and Serviceability**, in which versatility and protection, technical service life, adaptability to climate change, branding and cultural heritage, availability of services in the building, cleanliness and maintainability are considered.

From the 4 categories, health and comfort is clearly the one which is most covered by research, technological development and indicators. From the European point of view, health and safety are areas which are well subjected to regulations and standards, both existing and under development. Comfort seems to be less covered by regulations, but is clearly well addressed in standards. The other 5 sub-categories seem to draw in general less attention from policy makers, industry or the public. In the future this may however change, certainly if the indoor performance becomes a well-known concept for which business opportunities are demonstrated.
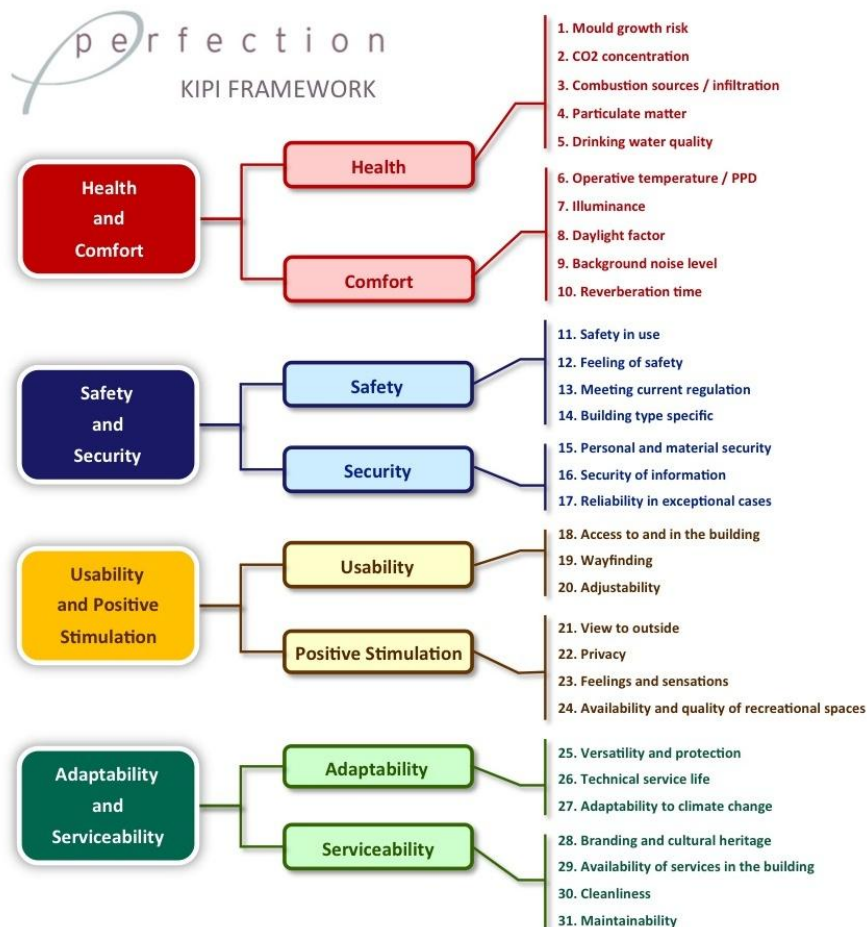
Fig 1. The final Perfection KIPI Framework

WORK PACKAGE 2: USE OF INDICATORS

The PERFECTION Toolbox and Case Studies (D2.1&2.4)
The PERFECTION case studies and excel-based toolbox form a significant element of the project and were used in the first phase of the project to provide input to the development and understanding of the KIPI indicators and how they can be used in practice.

The PERFECTION Excel-based toolbox

The first step consisted in the development of a model and an experimental testing toolbox. The tool served for the evaluation of the case studies based upon the performance indicators listed in the KIPI Framework. The indicators list that was initially included in the toolbox was

derived from the first version of the indicator framework but, during the project, the toolbox followed the evolution of the KIPI framework, and was thus updated along the way.

The indicators used in the toolbox (see figure 2) can be assessed into two different phases of the building life. They can be assessed during normal operations that are performed inside the building (**assessment in operation**), or they can be assessed during the design phase (**assessment in design**), when a new building is being built or is undergoing a renovation process.

Fig. 2. Excel toolbox screenshot

The indicators can be assessed in a simple way, by means of site visits, user surveys or reviews of design plans (**simple assessment**). However, for some indicators it can also be useful to perform a more detailed assessment (**detailed assessment**), provided that additional information is available. Whatever assessment method is selected, the indicators are evaluated against five performance level (from A to E, where A is the highest and E the lowest).

Some indicators defined in the framework cannot be applied or are simply not relevant to all the building types. In order to deal with this a first estimation of the indicator impact on different building types was provided.

The first version of the toolbox that was created is based on an Excel sheet. It is composed of two main sections:
- General Information, containing some general information in order to provide a synthetic description of the building under analysis.
- Indicator Evaluation, with a separation regarding the assessment during the design phase and the assessment in operation.

The Excel sheet also contains a column for comments related to each indicator and a weighting cell. However, with the evolution of the project, it was decided to include in the last version of the Excel, a new section with a weighting system. The user has now the choice to select the default weighting system applicable to the kind of studied building and proposed by the PERFECTION consortium, or to use a personal or organizational weighting system (according to his own agenda and priorities).

The Case Studies (D2.4)
The case studies have been set up in two phases. In the first phase, a number of buildings, 5 in total, have been evaluated in a kind of iterative process during the development work associated with the framework and toolbox:
- A housing renovation project in Belgium
- A new build hospital and an existing hospital in Finland
- An office building in France
- A redeveloped historic building in Italy
- A university office and teaching building in the Netherlands.

Ten case studies have been added to this in the second phase. This 2nd phase has been undertaken over the period June 2010 to May 2011. The case studies include shopping centers, further offices and domestic premises. The Phase 2 case studies have been analyzed using the toolbox described before.

Once the PERFECTION Decision Support System (DSS) software was available, both Phase 1 and Phase 2 case studies have been submitted to it. The full findings from Phases 1 and 2 have been then taken together in order to produce the final summary report on case studies.

The PERFECTION Products and Technologies Database (D2.3)

The PERFECTION (products and technologies) service aims to provide a commercial platform, in the form of a search engine for locating all sorts of manufacturers, distributors, resellers of products that are, in some way, affecting positively a subset of the PERFECTION KIPI Framework and are, in this way, contributing to a better indoor environmental quality. The PERFECTION products platform directly brings into contact indoor environmental quality product providers and potential product buyers.

The web site dedicated to the promotional tool is available since September 2010. It is on line at http://products.indoorperformance.net. A screenshot is taken up in figure 3.
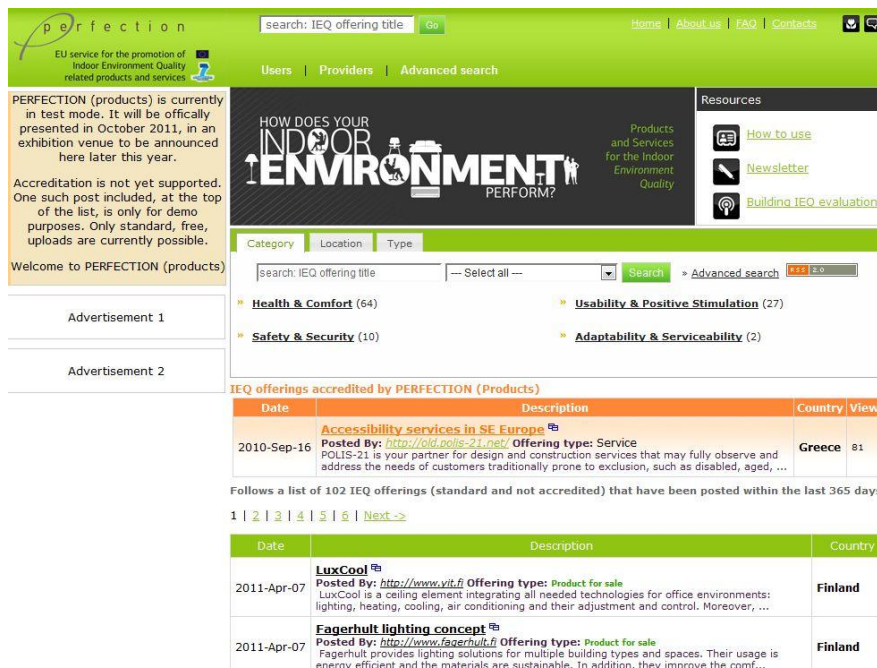
Fig. 3. A screenshot of the PERFECTION Products and Technologies Promotional Service.

The tool has been publicly available since June 2011. Indeed, the consortium has been filling the database of this tool with technologies and products identified by the consortium and the CES members. A letter has been prepared addressed to manufacturers and companies involved requesting editing and approval of information. This same request has been placed on the website.

The aim was to develop based upon the feedback a business case for this promotional service for indoor environment products, tools and technologies. If considered useful, the tool will be adapted in order to allow products.indoorperformance.net developing a transparent, long-term relationship with its users, which are on the one hand product and technology providers and on the other hand users and potential clients.

Indoor environmental quality product and technology providers are able to access the service in order to add information about their products and their contact data while potential buyers can search or express their interest for a related product. Visitors to the service are able:

- To freely browse through all the service content; this includes all the product information published as well as all its provider related information.
- To search and find products that are impacting upon a given KIPI indicator, that the visitor can select upon his interests.

The PERFECTION Decision Support System (DSS) for Buildings (D2.3&2.1)

The PERFECTION Buildings Tool at http://www.indoorperformance.net has been designed as easy-to-use and free-of-charge service, accessible from real estate and construction industry experts to citizens. The service supports building owners, managers and designers in decision-making by showing indoor environment quality ratings for building projects.

Registered users are able to add projects, with the permission of the building owner. The added value of the service is indoor environment performance calculations, for which a

methodology has been developed in the PERFECTION project. The following KIPI scores are calculated for buildings of various types, during their design or operation stages:
- Total KIPI score
- Category KIPI scores
  - Health and Comfort,
  - Safety and Security,
  - Usability and Positive Stimulation, and
  - Adjustability and Serviceability.

The official PERFECTION calculation module integrates PERFECTION developed European-level weights for Offices, Schools, Housing, Hospitals, Exhibition, and Other building types. The following image shows three basic steps for registered users to perform the addition of a new building project.
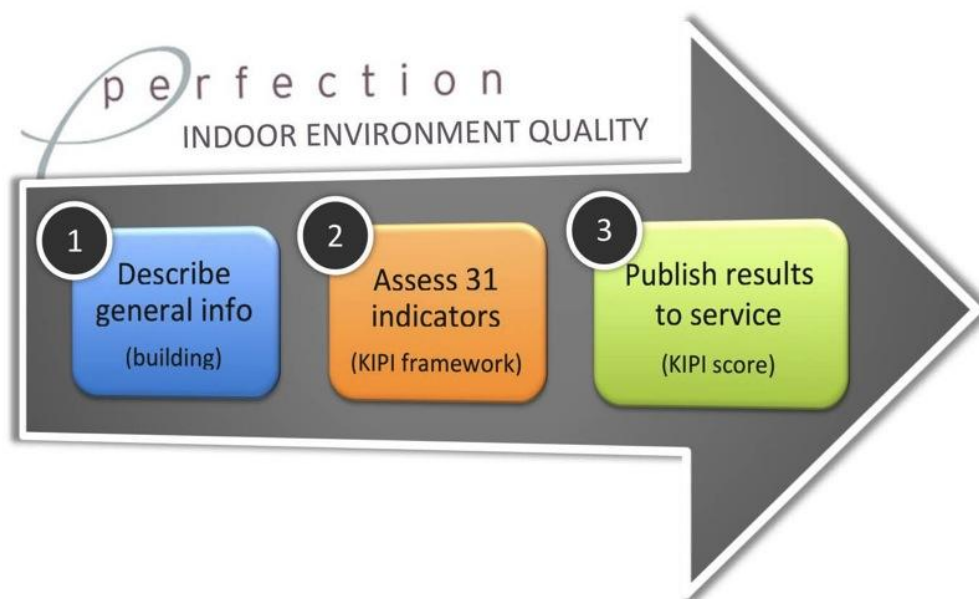
Fig 4. The Model behind the PERFECTION tool

The site map contains public (unregistered users, accessible for everyone) and private (registered users) interfaces. Registered users are able to add a new building project and optionally publish results to the public SHOWCASE. Published projects are visible to everyone. Citizens are able to see web report of the building projects in the SHOWCASE, but only the registered user who added the project has the related Excel/PDF exports.

The website hosts a second so-called adapted version of the KIPI based building evaluation tool. This second (see figure 5) offers more freedom to the user, in terms of selection of indicators, setting personal or organizational weights, adding specific indicators, etc. Whereas the official version of the tool allows benchmarking across Europe, the second is more oriented to commercial use within organizations who want to set and respect a limited number of IP objectives.

Fig 5. The Perfection Decision Support System (Evaluation Tool) – Adapted Version

WORK PACKAGE 3: POLICY RECOMMENDATIONS

The Context

One of the work packages defined in the PERFECTION work program was devoted to the formulation of policy recommendations. As the PERFECTION project is a EU-funded project, the aim was to make reference to European regulations and initiatives, such as the Energy Performance of Buildi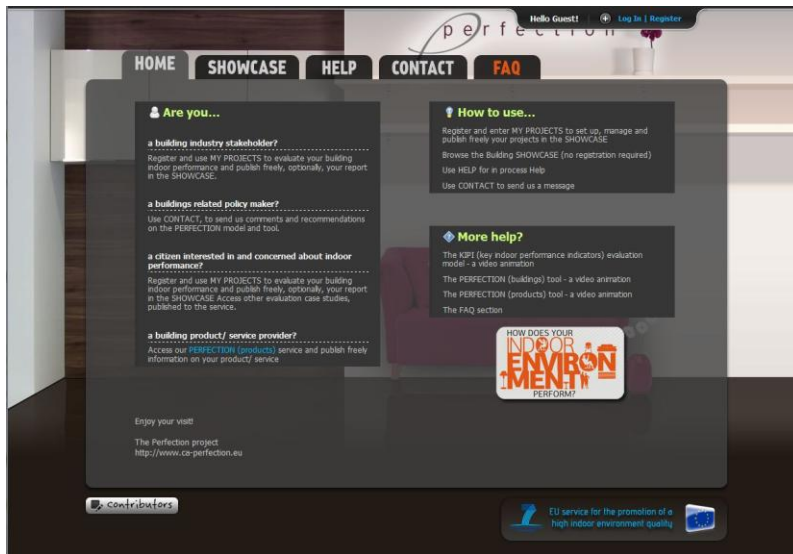ngs Directive (or EPBD Recast), the Construction Products Directive (in the near future Construction Products Regulation, CPD or CPR), the European Environment & Health Action Plan (EEHAP) and the Green Public Procurement Policy.

The policy recommendation work of the project was organized based upon four logical and consecutive deliverables:
- A report on indicators, design and technologies including the barrier and incentives (D3.1)
- A report on design and technology needs and priorities (D3.2)
- A PERFECTION Policy Support paper (D3.3)
- A PERFECTION Indicator Roadmap summarizing the work the work package (D3.4)

The works started of course from the PERFECTION KIPI Framework itself. Having a look to the 8 sub-categories of the PERFECTION KIPI Framework, it seemed logic to make a distinction between those categories which have to be addressed by regulations and/or policies because they refer to the physical integrity of the users and occupants of the building, and those categories which have more to do with the quality of the building in terms of well-being, impact on sustainability and design. Health and Safety clearly belong to the first group, while the other sub-categories are part of the second group. The Comfort topic is situated somewhere in between. The difference between the 2 groups is that they are treated differently in policy matters. Chances are big that this will remain so in the future.

The PERFECTION KIPI Sub-Categories in Policy and Regulations

The Health category refers clearly to 2 regulatory frameworks, the first one linked to the CPD, and more specifically the third essential requirement hygiene, health and the environment, the

second one being the Drinking Water Directive (98/83/EC). As the protection of the consumer or user stands central in these directives, it seems logic that most indicators falling under this sub-category are regulated, either on the European or at the Member State level.

The Safety sub-category has a similar aim. Demanding safety in indoor environments has everything to do with the protection of the user of the building (and the objects which are present in the building). As such, it is logic that regulations and standards address safety of buildings and indoor environments in all its aspects. The CPD, now becoming the CPR, addresses safety through at least 3 of the essential requirements, i.e. mechanical resistance and stability, safety in case of fire and safety (and accessibility) in use. The safety of the indoor environment is also addressed by other regulatory frameworks, such as those addressing the single markets for goods and the safety of consumer products (such as the Machinery directive for instance).

Security seems to be different as a sub-category compared to Health and Safety. Indeed, whereas health and safety clearly focus on the physical integrity of the users themselves, the security sub-category refers to a series of other aspects. Personal security is for instance only in a number of buildings (such as public or defence related buildings) really relevant. The importance given to material security and security of information will highly depend on the type of building. As such, it seems logic that the security sub-category is less covered by regulatory requirements. The initiative to put requirements for a particular building and/or indoor environment is left to the market.

The Comfort sub-category is from the viewpoint of the user a very relevant one as it directly affects well-being. As such, the relevance of the performance indicators addressed in this sub-category will be quite apparent to most users. From the regulatory point of view, comfort-related issues may be addressed, but much will depend on the type of building or the comfort issue under consideration. Lighting requirements are for instance to be found in regulations affecting the quality of the working environment. On the other hand, acoustical requirements are considered in the CPD through the essential requirement protection against noise, and are sometimes integrated in member states' building regulations. The EPBD itself deals partly with the comfort issue through its article 1, in which it is stated that the directive is promoting the improvement of the energy performance of buildings while taking into account indoor climate requirements. As the term 'requirements' is used, the focus is probably more on health-related issues than on comfort. Indeed, for the regulator protecting health is a major and priority issue whereas comfort is more situated in the market play: comfortable buildings will have a higher market value.

With regard to the Usability sub-category most of the elements covered are not integrated in regulations, but are considered in voluntary initiatives and standards. The topic of adjustability is for instance quite interesting when you are discussing sustainability aspects of indoor environments and buildings. The exception is of course the access performance indicator, which addresses amongst others the level of accessibility towards people with disabilities or ageing. This particular indicator is covered by regulation, as both the CPR and the EPBD address accessibility as an important topic and most member states have defined specific regulations addressing the built environment and the buildings accessible to the public. From the societal point of view usability seems to be an important topic for future policy work. First of all, the general objectives defined in European directives and regulations need to be translated in practical requirements and standards. Secondly, as buildings and built environments have a long life and a slow replacement frequency, addressing usability in regulatory frameworks and initiatives may have important consequences in the long run on all dimensions of sustainability.

Together with adjustability, adaptability of indoor environments is clearly an important performance indicator category if you think about the long term existence and use of buildings. Buildings and indoor environments (can) become part of the cultural heritage of the future, and need to be designed and built with an adequate technical service life. Moreover, they have to be robust enough in order to be resistant and adapted to the effects of climate change. Most of these concerns are not dealt with in current regulatory frameworks.

The same holds for the sub-categories positive stimulation and serviceability. Both aspects offer clear advantages for owners and/or users of buildings and indoor environments, but are not addressed in regulations. The economic value of buildings with indoor environments having a good performance should however be positively influenced. As such, improving serviceability and positive stimulation in buildings is mainly a market concern, and less a policy objective. Although it must not be neglected that in specific building types, such as hospitals and rest homes, there are also clear benefits for society with for instance a better and faster revalidation and/or integration.

Report on indicators, design and technologies including the barrier and incentives (D3.1)
The objective of this task was to formulate a set of recommendations to the EC and the Member States with regard to incentives and barriers to new designs and technologies. The report lead to the following list of recommendations:
- Raising awareness activities - addressed to all & fit for purpose, including also cost analysis of how a new technology/method works in comparison to 'old' methods, well-prepared information campaign,
- Promote incentives developed by the authorities. Balancing of the demand and supply side as being crucial to entrench the innovations and benefit from them,
- The voluntary labeling (certificates/award systems), if supported by the government and widely recognized by the professionals, may also contribute to the uptake of e.g. green buildings concept. The KIPI assessment tool has also the potential to become or contribute to one of these labels.
- Suggest guidelines for the EC,
- Elaborate benefits of the technologies for the adopters as well as EC (structured list of benefits, to make them obvious).

Report on design and technology needs and priorities (D3.2)
This task was devoted to the identification of the needs and priorities for future technology developments to improve the quality of the indoor environment. The analysis started considering the "High Level Indicators" of the KIPI framework and then went deeper to evaluate each indicator. This approach was chosen as indicators belonging to the same group are often assessed through the same methodologies and technologies.

The analysis showed that several solutions are already available for building designers and managers. However, there is still a lot of work to do both from the point of view of the regulations and standards and from the point of view of technology innovation. It is also very important to design the indoor environment in an integrated way, optimizing the balance between the design approaches followed and the choice of the passive or active technologies to be installed to achieve the best performance.

Regarding regulations, the most important technical requirements can be summarized as:
- Harmonization of the reference technical parameters to evaluate the KIPI indicators among the different European countries, in terms of descriptors, assessment

methodologies and target values (acoustic descriptors, illuminance, thermal parameters, etc.)

- Definition of guidelines for cleaning, helping to identify the best solutions to guarantee a proper conservation of the building materials, and positive stimulation issues to help managers and designers to choose the best approach to improve the indoor environment quality
- Development of guidelines to develop materials and construction methodologies to facilitate the cooperation between building designers and constructors, also ensuring adaptability and a long lifetime of the building.

The last aspect considered was the analysis of the control technologies and methodologies. The major priority is to promote the diffusion of integrated systems with capabilities to control environmental parameters (temperature, relative humidity, light, noise, etc.) not only in different areas of the building, but also in the same room.

Policy support paper (D3.3)

The aim of Perfection's Subtask 3.3 was to deliver a Policy Support Paper with regard to the current standards and regulations. Relevant documents and policies, such as the CPD/CPR, EPBD, EEHAP and GPP, were of course to be covered in particular. This task based its work on the PERFECTION KIPI framework (Tasks 1.5 and 1.6) and on experts' contributions (partners, CES members).

First, a synthesis of the European policies related to the themes involved into the PERFECTION project has been carried out in order to identify ways of improvement. This synthesis was presented to the CES members during a workshop session held in Prague in March 2011.

Then a questionnaire regarding the main recommendations has been submitted in May 2011 to all experts involved in the PERFECTION project, leading to more than 20 contributions.

Finally, a synthesis of all of these contributions has been integrated into the task 3.3 report. The work was presented in SB10 Finland and SB11 Helsinki in separate policy papers, and was presented in the Business-Oriented workshop in Greece (November 2012) and the EC Policy-oriented event (December 2012). The report itself has been amended and completed step-by-step by the PERFECTION partners, but was finalized in October 2012.

Indicator roadmap (D3.4)

The roadmap summarized the work in different time scales. It was developed in collaboration with Perfection CES members and also validated in a SB11 Conference by a wider group of experts. The result of this task is summarized by the Fig 6 that indicates the priority of the development and implementation of indicators over time.

			0 to 1		1 to 5		5 to 10		over 10
HEALTH AND COMFORT	Health	1 Mould growth risk	🟢						
		2 Ventilation / CO2		🟢					
		3 Combustion sources / infiltration	🟢						
		4 Particulate matter		🟢					
		5 Drinking water quality	🟢						
	Comfort	6 Operative temperature / PPD		🟢					
		7 Illuminance		🟢					
		8 Daylight factor	🟢						
		9 Background noise level	🟢						
		10 Reverberation time				🟡			
SAFETY AND SECURITY	Safety	1 Safety in use		🟢					
		2 Feeling of safety				🟡			
		3 Meeting current regulation	🟢						
		4 Building type specific				🟡			
	Security	5 Personal and material security		🟢					
		6 Security of Information			🟡				
		7 Reliability in exceptional cases				🟡			
USABILITY AND POSITIVE STIMULATION	Usability	1 Access to and in the building		🟢					
		2 Wayfinding			🟡				
		3 Adjustability			🟡				
	Positive Stimulation	4 View to outside			🟡				
		5 Privacy		🟢					
		6 Feelings and sensations						🔴	
		7 Availability and quality of recreational spaces		🟢					
ADAPTABILITY AND SERVICEABILITY	Adaptability	1 Versatility and protection			🟡				
		2 Technical service life		🟢					
		3 Adaptability to climate change			🟡				
	Serviceability	4 Branding and cultural heritage				🟡			
		5 Availability of services in the building			🟡				
		6 Cleanliness		🟢					
		7 Maintainability			🟡				
31			6	11	8	5	0	1	0

Figure 6: Indicator roadmap. Implementation of Perfection KIPIs in different time scales (in years from now on.

Conclusion: recommendations to Improve Indoor Performance in the Future

If one aims to improve the indoor performance of buildings through developing or improving policy and regulations, one has to take into account the multiple dimensions of the indoor environment, which are themselves only a part of the many dimensions determining the sustainability of the building or built environment under consideration. Improving the indoor performance therefore demands a policy approach dealing on the one hand with the overall concept and on the other hand with the individual sub-categories and performance indicators.

A project as PERFECTION does help to put forward and increase the visibility of the indoor environment quality concept. A good understanding of what indoor performance is very relevant, and the KIPI framework certainly helps to bring the message and create awareness. Indoor performance is much too often restricted to indoor air quality, and the PERFECTION framework avoids such misunderstandings. Promoting the indoor performance concept remains therefore an important action point for the future. It can be realised amongst others:
- By stimulating indoor environment research and development of appropriate technologies.
- By promoting standardisation and developing assessment methodologies for individual performances and for global evaluations (being part of overall sustainability evaluations for instance).
- By issuing guidelines and codes of good practice.

- By integrating indoor environment quality in technical specification for public buildings and works, such as for instance schools, hospitals, etc.
- By developing educational programs and courses on indoor performance for specific target groups such as architects and designers, building professionals and students for the different building professions.

Besides the overall concept, policy initiatives can also address the individual sub-categories and performance indicators of the KIPI framework. As illustrated in the former paragraphs health and safety (and in a lesser way comfort) are already well integrated in the existing regulatory framework, but this does not mean that further work is not necessary. Research and technological development remains important in these areas. With regard to health a lot of work remains for instance to be done to better understand the effects of the different contaminants present in the indoor environment. Translating the safety requirements in practical guidelines and standards and in economic feasible designs stays an important challenge for the future.

Most of the other sub-categories can only be partially addressed by regulations. Setting minimal requirements for comfort, security, usability, positive stimulation, adaptability or serviceability is less evident for a regulator than for the health and safety sub-categories, where the risk for human beings is far more important. However, depending on the categories of buildings and the specific performance considered, the legislator may take particular initiatives. Examples are the accessibility requirement for public buildings which is present in most regulations of member states or the acoustical comfort and noise protection addressed sometimes in building regulations. Next to addressing and completing the regulatory framework, policy makers may stimulate the market to develop and use new technologies and designs in order to improve the quality level of the built environment by stimulating and financing RTD-work and voluntary initiatives, for instance through financial support or tax deductions.

1.4 Potential impact, main dissemination activities and exploitation of results

As a project PERFECTION was lucky and able to have already an impact during the projects' lifetime. The good understanding and collaboration in the consortium and between partners enabled the timely delivery of deliverables, reports, newsletters, workshops and tools. Thanks to this an extensive dissemination and interaction with the scientific, industrial and policy community could be organized, already during the projects' lifetime. As such, the short term impact of the project cannot be underestimated, and consists amongst others out of:

- About **14 scientific peer-reviewed papers**, presented during conferences where academia and industry could be reached. PERFECTION also presented **4 posters** at such conferences.

- **5 workshops**, focusing on the interactions with the PERFECTION Committee of Experts and Stakeholders, but also open to the public and including invited speakers

- **1 workshop with the EC**, to transfer and discuss the PERFECTION policy-related activities.

- **2 PERFECTION webinars** (in June 2010 and June 2011)

- **4 videos** on PERFECTION and tools available on You Tube

- **3 websites**, i.e. the mother website and the tool websites on buildings and products.

- **2 PERFECTION booths** at the SB11 Helsinki World Sustainable Building Conference and at the Green Expo of the Greek MoneyShow.

- **A Special Forum** on Indicators at the SB11 Helsinki World Sustainable Building Conference and **a conference session** during the same conference focusing on indoor performance and indicators, in which 4 of the 6 presented papers were PERFECTION-based.

- Presence and presentations in events, such as the ECTP Conference, the Belgian presidencies' initiative on indoor environment and health and standardization committees.

Thanks to the dissemination activities, PERFECTION was able to put forward **Indoor Performance as an important concept**, and to create awareness about the different components of IP. The PERFECTION KIPI framework appeared to be easy-to-understand, attractive and fit for communication purposes. The consortium never claimed that the KIPI framework was perfect nor complete, but it clearly had the advantage of simplicity, transparency and manageability. Thanks to this, a lot of actors came to realize that indoor quality is more than indoor air quality and health-related aspects.

The Indoor Performance (IP) concept itself, and its different components, allowed also identifying some **work items for the future**. These are amongst others addressed in the policy support deliverable reports and the policy brief. In areas such as health, safety and comfort, policy initiatives have already been taken in the past, and indicators were therefore judged to be mature for immediate implementation (see figure 6). The other indicator categories, such as security, usability, positive stimulation, adaptability and serviceability clearly lag behind and face longer implementation times. Making progress in these areas will depend largely on the efforts taken by policy makers to create frameworks and stimulate initiatives and the response of industry and the market. Three examples illustrate the potential impacts this may have:

- In the usability category, one of the performance indicators is "**access to and in the building**". In most European countries, accessibility is regulated or regulation initiatives have been taken, and in nearly all cases the focus is on the public environment. More stringent regulations in the public area and stronger demands from society which is ageing, will clearly stimulate (and in some cases already have stimulated) progress in this area. New and innovative products, technologies, care and services initiatives have been taken to respond to this societal demand and challenge. Thanks to PERFECTION this challenge is placed in a broader framework, in which the access element is part of the global indoor performance.

- The different elements of the "**positive stimulation**" sub-category have been put on the foreground thanks to the FP7 ENV call and the response of PERFECTION to this challenge. The work of PERFECTION showed that this area is not well enough covered by research and technological development, and that huge steps forward seem to be possible in this area. Investing in positive stimulation may have important societal benefits, largely depending of where the positive stimulation measures have been installed. In industry and work environments, such measures may lead to higher productivity and economic benefits. In schools, positive stimulation may help pupils to

stay focused and motivated. In shops, measures may help to increase sales. In hospitals and care facilities, positive stimulation may accelerate revalidation, increase quality of life and lengthen life. Studying impacts and quantifying costs and benefits seems to be an urgent need in this sector to enable further progress and stimulate investments.

- Due to the global challenges facing the world in the Energy and Climate debate, the construction industry is heavily concentrating on energy efficiency and carbon neutrality of buildings. A huge amount of RTD funds are now directed towards this long-term challenge with objectives defined for 2020, 2030 and 2050 with regard to energy use, carbon emissions and renewable energy (see the 20/20/20 objectives and the EU roadmap towards carbon neutrality). It is clear that the built environment, both new built and renovations, have an important role to play in this debate, but at the same time the quality of the buildings themselves may not be endangered by focusing solely on the energy and climate objectives. Indeed, as people spend more than 80% of their time indoors, the Indoor Performance is crucial to the well-being of people and society. The KIPI framework will help remind society to this equilibrium and will help to convey the message that **the future challenge is to build energy-efficient and carbon-neutral buildings with a high-quality indoor performance**. Moreover, the KIPI framework and the whole or partial uptake in sustainability assessment tools and objectives, will also help to improve the quality of these tools. Finally, the KIPI framework itself contains an indicator named "**adaptability to climate change**". This indicator stresses the importance of long-term views on buildings and the indoor performance. Indeed, buildings which are new built or renovated now, not only impact the energy use and carbon emissions of the future, but should also be flexible and adaptable to allow adaptations to an unpredictable future, and this at a minimal economic and environmental cost.

The different results of PERFECTION will be exploited by the consortium in many ways. In a direct way the consortium participants will use the KIPI framework and associated tools to impact:

- Education. Some of the participants do teach at universities and will include the framework in their courses.

- National regulations. Organizations involved in PERFECTION do have in many cases an advisory role in regulatory initiatives, such as the EPBD implementation or access regulation, and will put forward the IP concept.

- International standardization. During the lifetime of PERFECTION information has been transferred to CEN TC350 (WG5) and ISO TC59 SC17 (WG2), and this will be continued in the future.

- Certification. Many of the associated participants are involved in the development of sustainability assessment schemes or projects, such as BREEAM, SB Tool, VALIDEO, Super Buildings or Open House. The results of PERFECTION will be partially integrated and implemented gradually in these schemes.

- Networking and exploitation activities. Some of the participants will try to stimulate the use of the PERFECTION building tool on a local level, and with a focus on specific target building types. The main efforts are currently focused on the adapted version of the tool in commercial environments.

- Further RTD activities. Both on the level of the IP concept as on the level of the categories or performance indicators, consortium participants will continue RTD efforts. IPR agreements have been defined by which the source code on the tools have been shared between the PERFECTION partners. Most of the consortium partners are willing to collaborate in the future, but due to funding possibilities in Europe it is highly probable that RTD efforts will be undertaken at the national or interregional scale.

Finally, it has to be repeated in this context that one of the conference papers has been selected as Best Paper at SB11, and thanks to this, this paper will be reworked for a scientific journal. The paper will be published by the middle of 2012. Dissemination continues thus also on the scientific level.

1.5 Address of the project public website and relevant contact details.

The public project Website is located at http://www.ca-perfection.eu. The evaluation tool can be reached at http://www.indoorperformance.net and the product tool at http://products.indoorperformance.net. Any request concerning the project may be sent at perfection@bbri.be.