HVAC Applications in Domestic, Industrial and Agricultural Buildings.

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Introduction

In this session 14 papers are discussed covering a wide range of topics, applications and aggregation levels. Besides papers using different simulation tools, several field tests, experiments and theoretical approaches are discussed. The majority of the papers present applications in dwellings, but also industrial and agricultural environmental issues like those in greenhouses for the production of crops and livestock buildings (pigs) are discussed. Reading through these papers with all different topics, optimisation strategies, and contributions to building projects at different aggregation levels a common denominator was difficult to find. Reason for which the need was felt to start this paper with a general introduction describing: building projects, the parties involved with their individual objectives and possible optimisation strategies including obstructions for integral approaches, etc. On one hand this part is meant as a contribution to a greater understanding of parties involved to their relative contribution as a part of a greater optimisation process, on the other hand this part is used to discuss the contribution of the papers in this session as a contribution to the development of this field of knowledge.

HVAC Applications, active versus passive controls

The title of this session: “HVAC Applications in Domestic, Industrial and Agricultural Buildings”, seems to be unambiguous, but is it?

Let us discuss in somewhat more detail the first part: “HVAC Applications”, which stands for: Heating, Ventilating and Air Conditioning. This acronym is thereby formulated in terms of actions, actions to manage the indoor environment. Indoor environment in domestic, industrial and agricultural buildings. For sake of argument we will discuss the following part in terms of domestic applications and therefore define the indoor environment in terms of comfort (for instance indoor temperature Tind = Tcomf). For industrial and agricultural applications, however, other parameters for good indoor environments can be defined.

> Heating is the action to control the indoor temperature in the case Tind<Tcomf.
>
> Ventilating is the action to supply fresh air in a controlled way.
>
> Air Conditioning is mostly seen as a system combining ventilation and cooling.

In such a way defined it is already clear that HVAC is combining incomparable aspects. What is basically meant is some combination of:

Heating: controlling indoor temperature when Tind < Tcomf

Cooling: controlling indoor temperature when Tind > Tcomf

Ventilation: managing indoor air quality (IAQ)

From the last definition it is clear that ventilating is not a goal as such (as it is still often seen) but is meant to support the objective of managing the indoor environment, more specifically the indoor air quality.

Historically, ventilation was seen as a necessity to supply fresh air to spaces where people “polluted” the indoor air by their CO_2 production and emissions of bodily odours. From recent research it is seen that the indoor air quality, as perceived by humans, is determined by much more sources, such as: materials in occupied spaces, the HVAC-installation itself and the outdoor air quality.

It is therefore obvious that passive measures, such as source control, should be taken into consideration as well. This applies equally to managing the indoor temperature! Heating, cooling and ventilation are as such the active equivalents of managing indoor temperature and indoor air quality.

	Active measures	Passive measures
Tind<Tcomf	Heating	Design ^{1})
Tind>Tcomf	Cooling	Design ^{2})
IAQ ^{3})	Ventilation, local exhaust	Design ^{4})

ad ^{1}) Insulation, passive solar energy use, maximum use of internal gains, etc.
ad ^{2}) Minimise internal and external heat loads, use building-mass, etc.
ad ^{3}) Distinguish comfort and health effects.
ad ^{4}) Minimise internal and external loads, choice of materials, etc.

For all mentioned applications it is important to understand that active as well as passive measures to manage the indoor environment have to be approached on an integral basis. For active measures only it is obvious that, for instance, simultaneous cooling and heating is not desired as it leads to unnecessary energy consumption.

With the passive measures this is not so clear, as can be seen from a selection of possible contradictory optimisation strategies:

Winter	Summer
Maximum use of solar gains	Minimum solar heat load
Maximum use of internal gains	Minimum internal gains
Minimum ventilation irt heat losses	Maximum ventilation irt limited overheating in case of no cooling
Minimum window area irt heat losses	Minimum window area irt heat loads
but	
Maximum window area irt day-lighting	

Contradictory solutions can thus already be identified, from the perspective of HVAC-applications only.

Industry and Agriculture versus Domestic Applications

For both other applications: Industry and Agriculture the theoretic approach is alike, only limit values as well as parameters are different and are often not derived from well being of humans (comfort or health) but dictated by industrial or agricultural production environmental point of view. IAQ as seen from industrial or from a livestock building with pigs is considerably different and can in some cases be somewhat extreme as compared to domestic applications. The environmental specifications of a Cleanroom for instance can include particle specifications, limit values for chemical impurities as well as specifications out of the scope of the above mentioned comparability with domestic dwellings, like: Electro Magnetic Interference, mechanical vibrations, uniformity of air flow, etc. For heating, cooling and IAQ, however, the systems used are comparable as well as the problems during design, realisation and operation.

Building process, parties involved and differences in objectives

In building processes different parties are involved. Limiting to those most relevant for the indoor environment, we distinguish:

Principal

Architect

Consultant

    Suppliers

    Contractor

Facility manager

From experiences, two different type of principals can be distinguished leading to somewhat different approaches regarding optimisation dilemmas, being:

Project Developer

Principal/building owner

The project developer is mainly interested in minimising initial costs as his objective is maximising profits, being the difference between market value and initial costs. The principal/building owner is somewhat more interested in the other aspects (operational costs, energy consumption and functionality) as he is likely to be confronted with disfunctionalities during the life time of the building.

Often this difference in principals is followed by a comparable difference in facility management, done by a “professional” facility management organisation or by a (equally “professional”) technical department as part of the principals own organisation. Speaking in terms of customers wishes we now can distinguish 5 different parties, with different primary objectives:

Project Developer	Minimise initial costs
Principal/building owner	Minimise total costs
“Professional” facility manager	Minimise operational costs
Facility Mgt. own organisation	Optimise price/quality relation
Building users (Tenant)	Maximise functionality

These primary objectives are of course oversimplified characteristics of each party involved and are based on the author’s own experiences. They refer to a relatively small margin of room for optimisation left within the framework of market-conformity.

In addition the other parties involved are often limited to a specific interest as well. Again only simplified characteristics are given:

Architect	Aesthetics
Consultant	Minimise costs for guaranteed required performance

From the subject HVAC we already identified contradictory solutions to given problems in managing indoor environment. This list of participants with said differences in objectives will lead to even greater contradictory design choices, hence it appears: different optimisation strategies. If optimisations have to be carried through, which objectives have to be honoured?

Integral design, Architecture versus Installations

The integrated approach, as already stated, should take active as well as passive measures into consideration. In practice however the architect fixes in an early state of the design stage a great deal of choices such as: orientation, form and materialisation, often without real understanding of the implications on possibilities for passive measures. The consultant is thus left with a limited number of possibilities for an integral approach.

These measures are furthermore only contradictory from their direct consequences within the objective “managing indoor environment”. Investment costs for instance are well known to be minimised whereas this can be on strained terms with increased operational costs. In practice much more disciplines are involved allowing for many interactions, synergies but also other contradictions. In such a way aesthetical motives may prevail over functional, financial or even ecological ones. In this case it is important to understand that a perfectly controlled indoor environment in a badly designed building still results in an unwanted situation. All designs will be compromises where the degree of integration as well as the aggregation level (over disciplinary boundaries) at which this integration takes place, determines whether the compromise reaches out for a global or a local optimum.

From the indoor environmental point of view, three criteria to judge a design are most relevant:

> Functionality (Achievement of defined indoor environmental parameters over prolonged periods)
>
> Costs (Both initial and operational)
>
> Energy consumption (Both for production/construction as during life time)

Often Ecological consequences (other then energy consumption) are added, as well as other criteria addressing other disciplines. These three however describe in a comprehensive way what is achieved at what costs. During the building process these three parameters are (amongst others) optimised to one another. As they are neither independent nor really comparable this process is cumbersome. Energy consumption and operational costs can still be expressed in comparable units (yearly costs), but how are disfunctionalities in the realisation of indoor environment compared to these costs? Some research is done where these disfunctionalities were related to productivity and absence due to building related sickness, but still little is known.

Especially in the case of health threatening components in the indoor air the following estimated list can roughly demonstrate this lack of knowledge:

300,000 chemical compounds described in literature

30,000 used in buildings

3000 are defined as “Threshold Limit Values”, or TLV’s

30 defined indoor air limits

All of which are defined in a mono-chemical way. Nothing is known about combinations!

Industry and agriculture are somewhat in advance on this topic as sometimes relations are known between industrial yield or crop quality in relation to the indoor environment and as such can be expressed in financial consequences. But how do we express those consequences for domestic buildings?

If we increase the aggregation level at which the integration takes place, these problems increase too! How to compare for instance ecological consequences as a result of the use of certain materials to minimise or even exclude the use of otherwise required installations?

Trends, and an increased need for integral optimisation

In building processes, some trends emerge which supports the need for integral approaches of the optimisation process. They can facilitate the process of integration of design decisions and thereby support integrated optimisation processes. Some of these trends are:

Growing interest in total costs instead of initial cost minimisation only

Growing interest in Life Cycle Cost Analysis (LCCA)

Growing interest in energy consumption

Growing interest for good Indoor Environment, including good IAQ

Growing interest in ecological consequences of buildings

It may be clear that ever so many parties involved with (slightly) different optimisation strategies, as well as all trends mentioned the process of overall optimisation, is a difficult one.

Especially given the facts that: so little is known regarding consequences of design decisions from one discipline into others, the temporary character of the co-operation of different parties involved in building processes as well as the time-dependency of many parameters involved.

What is needed is sufficient knowledge about the interdependencies between disciplines, to allow for integral optimisation strategies, including differentiated accents given specific requirements for each project. The day to day practice, however, is a lot of trial and error, often not allowing for sound learning-cycles as are passed in normal industrial processes where more continuity between partners exists.

Trial and Error versus possible learning-cycles in building processes

Apart from (im)possibilities due to the temporary character of the co-operation between parties involved in building processes, two major possibilities in learning-cycles exist in building processes, a product development cycle and a project development cycle. Both are driven by the feed back of operational experiences, one giving feed back to the line of equipment developers into the supply line, the other feeding back unto the design and realisation process itself, both as indicated in the figure below:

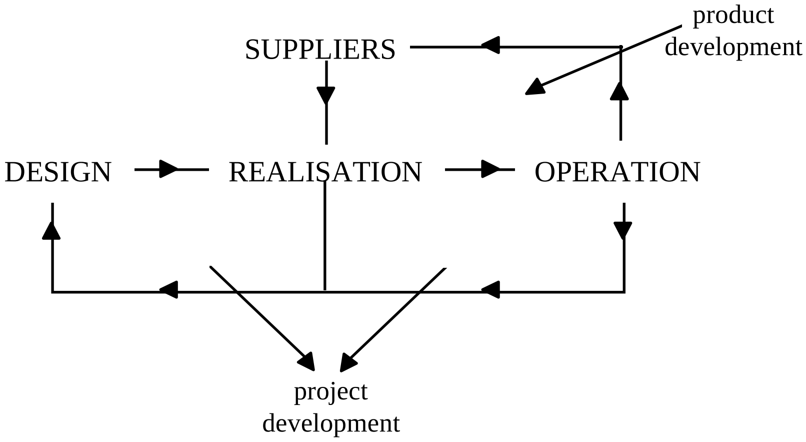

Figure 1. Learning-cycles/feed back loops from operational experiences in building processes.

Both cycles contain elements of:

Design / Development

Analysis / Simulation

Field tests / Experiments

In such a way both product development and project development are using the same data (field tests of operational projects) and are using comparable methods and simulation tools. These cycles are the basic driving forces within building processes for the development of knowledge regarding optimisation of processes and products.

Papers of session 2, numbers versus short names

All accepted papers are listed below, stating the paper ID-number and a short name given by the author of this paper in order for quick identification.

ID #	Short title
22	Greenhouse, condensation
86	Livestock., climate model
139	Heat recovery, efficiency
154	Ventilation systems, evaluation
165	Heating curves, wind speed
171	Hydrodynamics, simulation
243	Heat Exch., evap. cooling
257	Heat pump, multi-purpose
285	Emissions cement industry
296	Thermal hydraulic phenomena
301	Adsorption cooler, solar-hybrid
343	Heating curves, setting
345	Air filtration, design criteria
358	NO_X concentrations, cookers

Table 1. List of papers of session 2 with ID-number and short title, for further reference.

Projection of papers on building process dimensions

This paper has so far used a number of dimensions / aspects of the building process in order to place problems of different orders and different disciplines into each others context. We can now use these same dimensions / aspects in order to project all papers of this session to investigate the extend to which they contribute to the problems identified. The most relevant dimensions / aspects were:

HVAC	Application	Phase	Aspects	Type R&D
Heating	Industry	Design	Functionality	Design/development
Cooling	Domestic	Realisation	Energy	Analysis/Simulation
IAQ	Agriculture	Operation	Costs	Experiments/Field Tests

Table 2. Most relevant dimensions / aspects of building process, used so far.

Primarily we will use the dimensions:

Building Phase (major contribution to: Design, Realisation or Operation)

HVAC-system (Heating, Cooling or managing IAQ)

Application (Domestic, Industry or Agriculture)

All papers are, identified by their number from table 1., placed into a matrix consisting of the two dimensions: building phase and HVAC-systems considered.

	Design	Realisation	Operation
Cooling	-	243;301	-
Heating +Cooling	-	257	-
Heating	171,296	-	343
Heating +IAQ	-	139	22;86;165
IAQ/OAQ	154;345;358	-	285
Total number	5	4	5

Table 3. Papers of session 2 projected to: Building Phase and HVAC-systems.

Table 3. shows us a nicely distributed coverage of the individual papers over the 3 areas of interest, both phase-wise as over the HVAC-areas. The HVAC systems considered are sometimes mono-systems (heating, cooling and IAQ) and sometimes combinations (heating+cooling and heating+IAQ). The “OAQ” entry stands for Outdoor Air Quality and refers to a paper treating macro-emissions in an industrial environment.

Placing the papers from the cluster “Design”, in relation to the other dimensions/aspects considered, gives the following table:

paper #	Design/dvlpt	Anal/simul.	Exp./F.tests	HVAC	Funct/En/$	Application
171	-	x	-	H	F	D
296	-	x	-	H	F	D
154	-	x	-	IAQ	F	D
345	-	x	-	IAQ	F	I
358	-	-	x	IAQ	F	D
Total #	0	4	1			

Table 4. Papers within the cluster “Design”, projected on the most relevant dimensions/aspects (see table 2. for legends).

This table, showing the papers primarily contributing to the design phase of building projects, shows a strong preference for analysis and simulation of Heating and IAQ systems all of which are aimed on the functionality of the systems considered.

Placing the papers from the cluster “Realisation”, to the other dimensions/aspects considered gives the following table:

paper #	Desgn/dvlpt	Anal/simul	Exp./F.tests	HVAC	Funct/En/$	Application
243	-	x	-	C	F	D
301	x	x	x	C	F	A
257	-	x	x	H+C	F	D
139	-	x	x	H+IAQ	F+E	D
Total #	1	4	3			

Table 5. Papers within the cluster “Realisation”, projected on the most relevant dimensions/aspects (see table 2. for legends).

This table, showing the papers primarily contributing to the realisation phase of building projects, shows multiple attention for design/development, analysis/simulation and experiments/field tests, for a variety of systems, most of which are aimed on functionality. As can be seen from the detailed discussions per paper, this cluster of realisation all contribute to “project development”-cycles.

Placing the papers from the cluster “Operation”, to the other dimensions/aspects considered gives the following table:

paper #	Design/dvlpt	Anal/simul	Exp./F.tests	HVAC	Funct/En/$	Application
343	x	-	-	H	E	D
22	-	x	-	H+IAQ	F+E	A
86	-	x	x	H+IAQ	F+E	A
165	-	x	-	H+IAQ	F	D
285	-	-	x	OAQ	F	I
Total #	1	3	2			

Table 6. Papers within the cluster “Operation”, projected on the most relevant dimensions/aspects (see table 2. for legends).

This table, showing the projects primarily contributing to the operational phase of building projects, shows a differentiated attention for the different types of research, mainly on H+IAQ systems with nearly equal attention for functionality and energy.

From all three tables (4-6) we can conclude that very little attention is given to design/development (2), a mean score is achieved for experiments/field tests (6) tests and that the majority is aimed at analysis/simulation (11). Furthermore it is relevant to conclude that nearly all papers address 1 field of R&D (as a link in product and project development chains) only. Only 1 paper combines all three, and three papers combine two types of research.

Regarding the aspects functionality/energy/costs it can be concluded that the absolute majority (10) are aimed at functionality, 3 combine functionality with energy, one is treating energy only and none are treating costs!

All dimensions/aspects that are scoring above moderate are:

Domestic
Design, realisation and operation (equally)
Simulation
Heating and ventilation (IAQ)
Functionality

Combination of these aspects gives us: “Simulation of the Functionality of Heating and Ventilation Systems for: Design, Realisation and Operational Phases of Domestic Building Processes”, which is a reasonable description of the “mean” contribution to this session.

A final characteristic of the papers is the country of origin. Not relevant for the discussions, but still interesting: EEC (8), East block (5), Asia (2).

Detailed discussions per paper

Cluster Design (See table 3.)

171 Hydrodynamics, simulation

Radiator valves influence to hydrodynamic performance of water heating system network.
Marjonovi□ Lj., Novoselac A., Belgrade, Yugoslavia.

A simulation of the influence of single resistance changes of valves to global network performance by analysing transient loads in two-pipe heating systems is described. It is a tool for design where in addition to static design rules an additional semi-dynamic analysis is made to investigate total system responses to help in realising stable hydraulic regimes. It is a theoretical approach, without experimental data.

154 Ventilation systems, evaluation

Tools for Evaluating Domestic Ventilation Systems (IEA Annex 27).
MΔnsson L.G., Tullinge, Sweden.

As part of the International Energy Agency Annex 27, this paper describes preliminary results of the subtask “State of the Art”. More specifically it addresses assumptions for the development of simplified evaluating tools regarding Indoor Air Quality. The paper starts with an interesting introduction describing the stock of dwellings in the 14 OECD countries, regarding mean size, occupation, ventilation systems and developments of these and other parameters.

It selects a limited number of building and operational use characteristics, in order to describe a wide variety of possible combinations. Furthermore it selects a number of IAQ characteristics mainly expressed in terms of “exposure”. With the help of the semi-multizone simulation code SIREN and some statistical analysis it is shown that, with a limited number of combinations, predictions can be made about the IAQ situation of a very large number of combinations. It is meant to support design and/or renovation processes for larger numbers of dwellings, where individual studies would be too costly.

296 Thermal hydraulic phenomena

A method of assessing the steps of the double regulating valves equipping the heating units of a cogeneration heating system.
Iordache F., Stoica M., Iordache V., Bucharest Romania

Theoretical approach to include thermal hydraulic phenomena in the design of vertical heat distribution piping. Results are given in graphs presenting the thermosiphon load and different load drops as a function of floor level. A method is given to asses required settings of the commonly used two way control valves.

345 Air filtration, design criteria

Design Criteria for Air Filtration in General Industrial Ventilation.
Hagstr m K., Hiltunen M., Holmberg R., Lehtim≅ki M., Niemel≅ R., Railio J., Siitonen E., Finland.

Interim report on a multi-company project within the Industrial Ventilation (INVENT) Technology Programme. It states that existing classifications like EUROVENT 4/5 and EN 779 are incomplete and are developed for test conditions only, whereas guarantees for operational in-situ performance during life time are required. It proposes a simple classification scheme, describing three categories with maximum allowable penetration levels of 10% at 5, 1 and 0.5 µm. This roughly corresponds with applications in the field of: ventilation, respiratory protection and fine particle filtration. It provides recommendations for different environmental categories and describes the main objectives of further research like: international guidelines, expert system for filter selection and filter performance data. Finally some laboratory test results are given where pressure drop and penetration is measured as a function of filter challenge. It is an ambitious total approach to support the design process of filter systems.

358 NOx concentrations, cookers

Insufficiency of natural ventilation against NO_x concentrations caused by domestic gas cookers.
Zorraquino M.J.V., Bilbao, Basque Country.

Some 64 dwellings in four regions, both naturally and mechanically ventilated, were measured as to NOx, CO_2 and CO concentrations due to gas-powered domestic food cookers. It is shown that often regulations are breached, especially regarding the peak concentrations of NOx and CO, even with the use of emission-approved cookers.
It is stated that in fact the ventilation criteria should be based on NOx levels, and not on the CO_2 levels as they usually are, but given the required ventilation rates it is proposed to apply local exhaust units. It is a clear contribution to future ventilation requirements/systems based on field measurement.

Cluster Realisation (See table 3)

243 Heat Exchanger, evaporative cooling

Indirect Evaporative Cooling of Low Energy Building.
Arkar C., Medved S., Novak P., Ljubljana, Slovenia.

Based on previous research into a cheap material, suitable for the production of heat exchangers based on indirect evaporative cooling, results are presented of thermal analysis of a single family house using the TRYNSYS simulation program. Results are given of temperatures and comfort levels obtained in comparison with a simple ventilation system with four air changes per hour. It is a contribution to a product development cycle, based on simulations and analysis.

301 Adsorption cooler, solar-hybrid

Development of an Advanced Solar-hybrid Adsorption Cooling System for Decentralised Storage of Agricultural Products in India.
Mande S., Ghosh P., Kishone V.V.N., Oertel K., Sprengel U., New Delhi, India and Stuttgart, Germany.

In co-operation between TERI (India) and DLR (Germany) and funded by the EC (DG XII), research is done into the development of a combined biogass dual fuel energy and solar-hybrid silicagel/methanol adsorption cooling system for agricultural applications in India. It is a highly integrated system combining several sub-systems. The paper describes both theoretical backgrounds, sub-system selection criteria, experimental measurements as well as system simulation results using the TRANSYS programme. It also describes economic analysis as well as its CO_2 emission potential. In total it is an interesting paper of high quality describing all facets of product development which potentially contributes to the solution of a real problem in India.

139 Heat recovery, efficiency

Efficiency of a Double Block Cross Flow Balanced Ventilation System with Heath Recovery.
Liem S.H., Kalkman C., van Paassen A.H.C., Kouffeld R.J.W., Delft The Netherlands.

Within the framework of the ”Urban Villa”-project of IEA task XIII, a balanced ventilation system is developed. This paper describes the laboratory tests of this unit, including a heat recovery unit. Besides theoretical backgrounds and experimental set-up, results are presented, in terms of thermal efficiencies and yield of the heat recovery unit. It is stated that the yield factor is a better characterisation of the performance of the heat recovery unit than thermal efficiency only. Special attention is given to air leaks. It is a high quality paper describing experiments in a product development cycle.

257 Heat pump, multi-purpose

Development of a multi-purpose heat pump for domestic appliances.
Vanparys H., Berghmans J., Leuven, Belgium.

Three parties: KTH (Sweden), ATECNIC (Portugal) and KULeuven (Belgium) are working together in the framework of the EC-programme JOULE, to develop a multi-purpose heat pump for domestic appliances (heating, cooling and providing hot tap water). Previous research led to an optimal choice of heat pump, dimensions and heat exchanger characteristics, after which the prototype was assembled. This paper describes the test results and evaluation of this prototype in terms of component analysis and proposals for improvement. This paper is also a clear contribution to a project development cycle.

Cluster Operation (See table 3)

165 Heating curves, wind speed

Influence of wind velocity to supply water temperature in house heating installation and hot-water district heating system.
□ivkovi□ B., Zekonja P., Ka□ar A., Belgrade, Yugoslavia.

A theoretical approach to the influence of wind velocities on the heat demand of dwellings and consequently on the required adaptations of heating curves controlling the heating systems, including district heating systems, is presented. A boundary wind velocity is defined in relation to building characteristics below which a minimum ventilation rate of 0.5 per hour should be established by opening windows etc. and the heating curve should no longer be lowered as to compensate for diminishing heat losses. It is a contribution to the operational stage of heating dwellings.

343 Heating curves, setting

The Heating Curve Adjustment Method.
Kornaat W., Peitsman H.C., Delft, The Netherlands.

Within the EC-programme SPRINT, a combined research project between CSTB (France), CSTC (Belgium), IBP(Germany), SINTEF (Norway) and TNO (The Netherlands), to test and improve an originally by CSTB developed method for determining the optimal setting of heating curves in practice.
It is based upon the assumption that most heating curves are not well set, for instance to compensate for other shortcomings. It describes a methodology to find optimum settings in a given building, based on some field measurements and analysis by the WINREG programme. It is stated that in practice often 5% of energy saving for heating is attainable. This paper is again a contribution to the operational stage of heating systems in dwellings and compartment blocks.

22 Greenhouse, condensation

Influence of Condensation and Evaporation on the Greenhouse Climate and its Regulation.
Pieters J.G., Deltour J.M., Belgium.

Crop production in greenhouses requires highly transmitting coverings, which mostly do not combine well with good insulation properties. The low surface temperatures lead to condensation which has negative effects on crop quality, ergonomics, fungal diseases and light transmittance. Energy consequences are more unambiguous. The latent heat of condensation leads to higher surface temperatures and by consequence to a lower heat loss, the condensation layer on the other hand can totally change the radiative properties of the cladding material. The paper describes the influence of 12 different cladding materials by using a TRYNSYS based dynamic greenhouse climate model. Results regarding the calculated auxiliary heat requirements (AHR) using the different materials show completely different consequences as compared to static methods based on U-values if condensation is taken into account. It is further used to contribute to the optimal control of greenhouses including the introduced vegetation instead of the normally used air temperature. It is a high quality paper applying theory and simulation in order to contribute to better designs as well as operations.

86 Livestock., climate model

Analysis of livestock environment control by simulation technique and field data.
Vranken E., Berckmans D., Goedseels V., Belgium.

A dynamic simulation model for analysis of livestock buildings for pigs describing temperature, humidity and gas concentrations is described to investigate the result of different algorithms for heating and ventilating. An optimised control strategy is developed using this simulation tool and is tested in 8 different locations over a three year period. The following advantages are found in comparison to traditional control strategies: 40 % reduction in energy consumption for heating, 30 % lower temperature fluctuations, reduced risk for cold draughts and 8 % lower ammonia emission. Predicted temperatures relate well to measured ones, however, temperature fluctuations at different locations are higher. It is a high quality paper describing both theoretical approaches, simulations and experimental validation. However, the authors should take more explicitly note of the developments within comparable research for domestic and industrial buildings. It is one of the examples where a complete project development cycle is passed and knowledge is developed for both improved designs as well as improved operations.

285 Emissions cement industry

Cement production and environment.
Huong N.T., Hanoi, Vietnam.

Only this paper is describing Outdoor Air Quality aspects. It is presenting field tests as well as analysis of data about emissions from three cement factories in Belgium, Algeria and Vietnam respectively. The deposition rates are presented as a function of source-distances and measured data is compared to simulation results. Analysis of the results show large differences in emissions and depositions, depending on processes, cleaning equipment (including maintenance performance) and meteorological conditions. Recommendations are made as to what type of cleaning equipment should be applied as well as the will to apply standards is stressed, especially in developing countries. It is a good paper combining theory, field measurements and simulation/analysis leading to a contribution for design as well as operational performance.

Conclusions

Cluster Design (5 papers)

The papers within the cluster “Design” contribute to this building phase by design rules and tools. Three papers address IAQ-issues, one of which from a health point of view. In most cases they are predominantly focused on functionality of the systems. In 3 out of 5 cases they describe a part of a larger research activity. All of them address 1 type of R&D only, necessary to contribute to the indicated project development cycles. In 4 cases the research is limited to academic research, whereas in 1 case industry is involved.

Cluster Realisation (4 papers)

All papers in the cluster “Realisation” contribute to product developments. Most of them are focused on functionality, some of them on energy, or combinations of these aspects. Three papers address more types of R&D required to contribute to product development cycles. The systems investigated are covering Cooling, Heating, IAQ and combinations of these three. All of the papers present part of a larger research activity. In all 4 research activities instustry is involved.

Cluster Operation (5 papers)

The cluster “Operation” contributes to this building phase through improved operations tools. It varies from heating systems (Heating Curves) through Greenhouses to Livestock buildings (pigs). The systems under investigation are Heating, IAQ and combinations. One is describing Outdoor Air Quality issues as a result of emissions from industrial cement production. The focus is functionality and energy, most papers are limited to 1 type of research necessary for project development cycles. In 1 paper industry is involved.

General

As discussed in the first part of this paper, building processes are characterised by many parties involved, often with different objectives, leading to trial and error optimisations. As each building project is by definition a temporary co-operation between different parties, building of knowledge is difficult. Two ways for feed-back of operational experiences leading to project development and product development cycles can be identified. Projection of the papers presented on these learning cycles provides us with an insight on how these R&D results evidently contribute to the building processes they are aiming at.

These processes are best performed by the papers from the cluster “Realisation”, which all contribute to product developments. In this cluster the best score is seen for integration of the different types of R&D necessary for the development cycles. In this same cluster also the highest participation by industry can be observed.

Both other clusters “Design” and “Operation” show papers much less integrated as the different types of R&D is concerned and the participation by industry is also much less. This might lead to research which is too “academic” in its approach to actual building processes, a complaint which is often heard and can objectively be seen from this investigation. This is perhaps the best way illustrated by the fact that no paper whatsoever includes costs to its investigation to an appreciable level.

The product development type of research is of course easier to initiate with industry, as continuity of partners involved is guaranteed. Comparable project development types of research is much more difficult to initiate due to the temporary co-operations. The building industry itself is furthermore rather conservative in its efforts to innovate. Real improvements however will only be possible through combined activities fed by operational experiences. Only by combined projects, closing the learning cycles will lead to the knowledge required for real integral design, leading to controlled optimisation processes.

The challenges which are confronting the building industry however are immense, both from a technical, social and ecological point of view. We will have to broaden our scope of research as to include all relevant disciplines to be able to confront these challenges in the coming decades. Closing the development cycles as indicated in this paper is essential as is active participation by Industry.

Liturature

1. Arkar C., Medved S., Novak P., Ljubljana, Slovenia: Indirect Evaporative Cooling of Low Energy Building (paper 243).

2. Hagstr ¯m K., Hiltunen M., Holmberg R., Lehtim≅ki M., Niemel≅ R., Railio J., Siitonen E., Finland: Design Criteria for Air Filtration in General Industrial Ventilation (paper 345).

3. Huong N.T., Hanoi, Vietnam: Cement production and environment (paper 285).

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