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Waterford Institute of Technology, Tourism and Leisure Building

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Abstract

The Tourism and Leisure Building at Waterford Institute of Technology contains all of the passive design elements that would be expected in a landmark environmentally-conscious educational development. The design however also addresses energy conservation in complex, high-energy kitchen systems in an innovative way, bringing a new level of environmental performance to catering in Ireland.

A new standard

The Tourism and Leisure Building presented a series of exciting design challenges, the most significant of which was the control of environmental conditions within its compact training kitchens, while minimising the building's environmental impact.

There were several precedents for this type of building, both nationally and internationally, and these were studied in detail. Making significant improvements to the environmental performance of this building type required a first principles approach, and the abandoning of any pre-conceived ideas on how the design of the building and its systems should be approached. The result was several new ideas that not only produced a successful design for this building but offered useful lessons for the design of future catering facilities. It was the designer's intention that the building would prove to be an educational tool in every sense of the term.

True first principles innovation and building optimisation cannot be achieved if unnecessary constraints are applied by isolating concepts to a single discipline. This is why an integrated approach to design was essential for this project, with the buildings shape, form, orientation, and facade developed with a full under-standing of its impact on the systems and environments that it contained.

A study of the building demonstrates that many of its visual elements have been moulded around the desire to optimise the building's environmental performance.

While the approach to the building's kitchen spaces stand out as a new contribution to building design techniques, the design of the rest of the building and systems also merit exploration as they follow many principles of passive design and have offered some useful contributions to the study of passive building design.

Low energy kitchen design

The building brief called for the accommodation of eight teaching kitchens. The two production kitchens and the pastry and larder kitchens are relatively typical kitchen spaces but the four training kitchens instantly presented themselves for special consideration.

A training kitchen is characterised by an extremely high density of cooking equipment spread evenly throughout the room. The traditional approach to this type of space is either to install a significant, energy-hungry air conditioning system or to accept the extremely hot temperatures that will result.

The treatment of the training kitchen must also take into account the following:

- A large proportion of the heat generated is radiant which makes it more difficult to address.
- Gas burning equipment can generate high levels of combustion waste gasses.
- The spread of equipment makes it difficult to capture heat at source.

The logical starting point for the design was the reduction of source heat gains which involved a detailed examination of the catering equipment required. A brief analysis of the catering equipment identified significant inefficiencies and poor associated energy performance. Much of the energy delivered to catering equipment was found to transfer to room gains with only a small proportion delivered to its target product.

A study was then carried out of alternative recently-developed equipment that offered an improved efficiency. While it would be interesting to use advanced low-energy equipment throughout the facility, it was important that the students be exposed to a variety of catering equipment and, for this reason, it was not possible to install the advanced equipment identified in all kitchens. The design team however overcame this barrier by proposing a solution to the client which involved the dedication of one of the kitchens as a *"kitchen of the future"* which would contain only low-energy cooking equipment such as induction cookers and infra-red salamanders. This was a brave move for the college who have embraced the concept and will use the kitchen to train the next generation of chefs in the concepts of sustainable cooking.

The use of electric induction cookers is not necessarily an intuitive low energy selection as they rely on carbon intensive electricity; however they are so much more efficient than traditional hobs that

the net effect on both the reduced direct energy requirement and the space cooling requirement was significant when compared with natural gas hobs.

The efficiency of an induction hob is derived from both its direct heating of the product without waste and also from its ability to turn off automatically and instantly when a pot is removed. (It must be remembered that traditional cooking scenarios involve leaving a gas hob on continuously even when not in use, due to the inconvenience of the relighting cycle).

Even in the kitchens that contained traditional equipment a number of potential efficiency improvements were identified such as appropriately-shaped hob outlets and improved equipment insulation.

The design team used this opportunity to call on the catering industry to introduce an equipment efficiency rating system similar to that used for domestic appliances as this was not required at the time of design and was a considerable contributor to the poor standards of catering equipment energy performance at the time.

Heat gains – solar

Following the minimisation of equipment loads and heat gains, the next logical step was to consider solar and lighting gains.

Lighting gains were easily reduced through the use of high frequency T5 fittings and associated occupancy detection controls (which were not commonly used at the time of design).

Natural light is very beneficial in kitchens and it was important that the design offered quality daylight to the kitchens but a number of innovative concepts were required to reduce associated solar heat gains to the south-facing kitchens.

The building is sculpted to offer natural shading to the glazing and the kitchen glazing is further protected through the use of innovative, solar selective light shelves built into the glazing units. This concept continues up the building to provide natural solar protection to the building's computer rooms which are also almost entirely naturally ventilated.

The benefits of daylight are much greater than the offsetting of artificial light. Natural light introduces a sense of contact with the external environment, a natural variety and sense of orientation and location within the building.

The kitchens are relatively deep due to layout constraints but as engineers BDP developed a special internal roof light configuration at the back of the kitchens that linked with the external environment via the atrium and served several functions. The roof

light offered a contact with the external environment but also introduces a special link between the calm buildings circulation and the active kitchen facilities through a visual link overlooking the kitchen from the atrium. This link allows the building's students and visitors to experience and appreciate the activity housed within the building.

This internal roof light within the kitchens required some significant engineering in order to prevent condensation from the humid kitchen environment and a build up of grease on the glazing. The use of the building over the last year has demonstrated that the air injection technique used in conjunction with the careful selection of equipment, including a dry bain-marie (to prevent steam generation), was extremely successful.

The systems

Once the source of heat gain had been addressed and attenuated as much as was practical, it was necessary to select the mechanical systems required to remove heat from the space and to introduce fresh, cool air to the kitchens.

Each kitchen type had to be examined separately to determine an optimum solution.

Production kitchens

The production kitchens contain islands of equipment that are tightly gathered together to form a single concentrated heat source.

For these rooms the most appropriate solution is to remove heat at source through the use of a kitchen canopy directly above the cooking equipment. Many traditional canopies are designed on the basis of a fixed capture face velocity which results in considerable over-sizing of the flow rates required.

The modern hoods used for these production kitchens are carefully aerodynamically profiled with the extraction placed towards the outside face of the canopy to minimise the capture-velocity to approximately half of that traditionally required.

Consideration must also be given to the introduction of fresh air and the canopy location affords the opportunity to supply fresh air through the face of the canopy directly in the working area of the cooks. This approach maximises the cooling effect of this fresh air both through the delivery of external air to the occupied zone and also through the use of air movement in the occupied zone that improves the sense of fresh air cooling.

The result was a low volume air supply system that produces a very comfortable environment without the need for air conditioning.

The controls strategy used for the production kitchens also works hard to reduce energy usage.

During low load conditions, it turns off the supply air and opens a series of motorised windows. It then slowly ramps up the air flow requirements to match the load.

The use of opening windows in kitchens in the form of a mixed-mode strategy is a low-energy solution that is often ignored due to complexity of control or fears of contamination.

Contamination is easily handled through the use of fly mesh screens on the windows and the controls strategy was carefully developed to include routines that close the windows during particularly cold or windy weather when draughts may be a concern. Local window over-rides are also provided allowing the users to open, or close the windows for a number of hours before the controls system resumes control.

Training kitchens

The training kitchens are a very different case as their loads are more evenly distributed throughout the room. The use of canopies within a training kitchen would not be appropriate for several reasons:

- The entrainment area required would result in air flow rates that are considerably higher than required by alternative solutions due to the large total entrainment area required.
- Visual continuity is particularly important within a training kitchen where a single chef must lead a large class.
- A large number of protruding canopies would obstruct the use of natural light in these spaces.
- The large number of workstations provided would result in a high cost solution.

A ventilated ceiling offers a useful solution for this room type as it is held out of the main operating zone and extracts evenly over the full room. A ventilated ceiling does not require any particular

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entrainment velocity to work effectively and works well with particularly low flow rates.

Traditional ventilated ceilings are fitted with both supply diffusers and extract grilles at high level within the ceiling and are fed by an air conditioned air supply. The result is a highly carbon intensive solution.

The removal of air conditioning from these rooms was important in order to minimise their carbon impact and an innovative new solution was required to avoid the need for air conditioning.

The difficulty with high level supply air in a kitchen is that the temperature at ceiling level is very high and air introduced instantly entrains its surrounding hot air. For this reason the supply air must be cooled considerably, simply to reach the occupied zone successfully.

A displacement ventilation solution allows air to be introduced within the occupied zone, where it flows across the room, is heated by heat gains and rises to high level for removal. This strategy offers the occupants air at the coolest possible temperature and leaves them standing in a pool of cool air. The air is drawn naturally to the locations where it is most needed by the room's heat gains.

At the time of the building's design there were no previous examples of the application of displacement systems to kitchens in Ireland and we were also unable to identify any international examples of its application to kitchens. Its successful use is therefore important in the forming of a useful case study.

The design of a displacement system within a kitchen, however, offered some technical challenges in determining its performance in the absence of any precedents. The effects of displacement ventilation is traditionally calculated through the use of formulae that rely on the assumption that heat-rise with height within the room is linear and uniform at all lateral points within the room. This assumption does not however hold for a kitchen design.

A kitchen is characterised by a series of high-intensity point loads and a significant three-dimensional natural plume transfer mechanism takes place that would lead to significant errors if a linear, two-dimensional model was used.

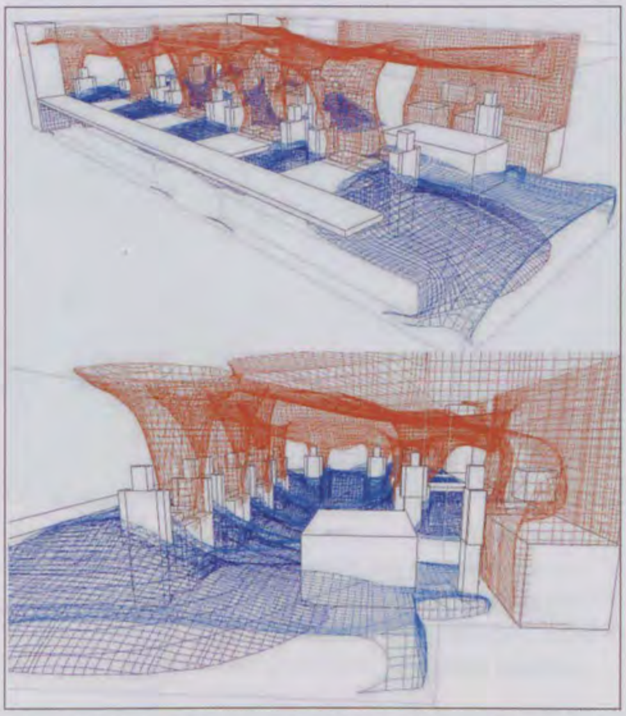
An advanced three-dimensional computational fluid dynamic model was required of air flow within the kitchens to determine the systems effectiveness.

The benefits of the displacement approach over the traditional high level approach can be visualised in the accompanying images.

The first image (below left) shows the temperature distribution within a traditional kitchen design, and the second shows the improvement achieved with our design concept under identical air flow conditions.

The temperature to colour scales uses are the same for both images so the benefits of the displacement system are self-evident from the images below.

The concept can be further analysed by the isotherm simulation image (below) which shows cool air flowing in at low level and the kitchen hot spots contained over cooking areas. The non-linearity is clearly visible from the image.



Computational fluid dynamics (CFD) is often used purely for illustrative purposes and it is important to test the benefits of its use by asking the simple question: What design changes were made as a result of the CFD analysis?

In this case there were a number of important design outcomes of the analysis; the first was the re-arrangement of some of the equipment within the room. It became evident that the gas cooking equipment which provided higher heat gains should be located away from the area of the room that was also subject to solar heat gains as the combined effect produced a local hot spot that was easily eliminated through the relocation of equipment.

The results were also used to optimise the location of supply air grilles to hold cool air at low level as long as possible and avoid forced pluming of cool air.

The results of the CFD analysis were also used to determine the design flow rates required to hold a cool air zone within the occupied zone.

The use of CFD was therefore vital to the success of the project.

It is also important to ask if the analysis was accurate and, to answer this question, a number of load tests were carried out on completion of the building. Temperatures were measured at a number of locations and elevations within the kitchens during the load tests and were found to be almost identical to the simulated results.

The load tests were also used to carefully test some of the complex control routines applied, and to ensure that carbon monoxide levels within the kitchens were not compromised by the low-energy, reduced-air volume strategies.

Once the displacement system had been designed and optimised, its controls were then optimised through a series of sophisticated routines that minimise energy use in a number of interesting ways. These are briefly outlined below:

- Natural ventilation is automatically used at low loads, through insect screened window openings.The automatic windows are carefully controlled to avoid draughts and remain open when appropriate at higher load conditions to form a hybrid ventilation strategy.
- Variable speed drives automatically adapt to the required load, taking into account the cooking load and the use of natural ventilation for make-up air.
- The kitchens automatically switch to high level supply during very cold conditions, operating as an interesting form of kitchen air heat recovery within the ceiling plenum and at high level in the room. This is a simple addition to the strategy that totally eliminates the need for pre-heating of the supply air during cold conditions.
- Carbon monoxide sensors allow the fans to operate at low speed without risk to the users. Load testing has demonstrated that even in the event of the failure of the carbon monoxide sensors, levels within the kitchen remain well within reasonable limits but the sensors provide a useful additional safety measure.

- The natural ventilation is used in conjunction with the mechanical systems in a hybrid mode to optimise internal conditions. There are user over-ride switches provided to allow the user to open or close the windows for a number of hours before control is returned to the building management system.

In a drive to use the building as a learning tool and to also optimise its control systems, a remote connection has been provided to the consultant engineer's offices which has allowed for interesting observation over a considerable monitoring period.

With complex controls systems it is always a concern that the users will find the system difficult to understand. However, observations both on site and through the remote system have shown that the system optimisation controls work well and that the users under-stand the systems operation. Part of the success of a complex controls system is maintaining a simple user interface and allowing appropriate temporary user over ride.

Hot water

Hot water use in teaching kitchens is significant and is required over a short period following each teaching session.

The environmental impact of the kitchen's hot water consumption is reduced by the use of dedicated condensing hot water heaters that were not available on the market at the time of tender but were added as they became available during the construction period, allowing the building to benefit from the latest technology available for this key energy consumer.

General layout

The building form was carefully laid out on a linear plan in order to expose south and north facades with the philosophy that due south gains can be dealt with effectively through shading methods.

The south facade is divided by a number of dynamic recesses, one of which is shown in the following photo (page 59). These recesses allow the drawing of daylight and natural ventilation into the building without exposing it to excessive heat gain. These recesses were carefully modelled to optimise the natural shading effects.

The south wall form is also assisted by the unusual use of a facade stack wall that conceals the large kitchen ventilation ducts. These ducts are carefully positioned to allow windows to project through the spaces between the ducts. The moving of the ducts to the external wall allowed a buffer zone to be generated that forms natural recesses to reduce solar gain. The co-ordination and optimisation of details of this type is a tribute to the design team's co-ordination of all disciplines.

A generous central atrium divides the building allowing stack ventilation, and also allows the night cooling of exposed internal block work which provides cooling to the majority of internal rooms as they back onto the atrium. This night cooling strategy provides the simplicity of night cooling without the security concerns of motorised external windows.

The building's main atrium is flooded with light, drawing light all the way down to the kitchen corridors, and transferring light through internal glazing to the kitchens.

A smaller secondary atrium is used to draw light to the back of the restaurant area where the food prepared by the students is consumed, offering further training opportunities for pupils.

Light is also drawn through the building with a series of roof lights, so that the building's users are constantly in contact with the natural environment.

Unwanted air leakage is the largest source of heat loss from a building of this type and an air tightness target of $5m^3/m^2/hr$ at a test pressure of 50Pa was achieved. This is a particularly impressive achievement when it is considered that no specialist sealants, membranes or blocks were used. An achievement that is often thought not to be possible with traditional construction and the

building has served as a useful demonstration of what can be achieved through careful detailing and quality workmanship.

Control

The building's controls also contain many innovative strategies that are designed to reduce the buildings energy consumption, including the use of direct weather compensated condensing boilers.

The board room and restaurant spaces also contain innovative control strategies that automatically detect the room's requirements and adjust the ventilation to suit, prioritising natural ventilation as their primary cooling measure.

The use of load-sensing control strategies offers significant advantages over traditional methods by reducing energy consumption and management requirements.

The building also contains an internet-based remote monitoring system which allows the design engineers to optimise the control systems and follow the buildings progress.

The building's lighting system is a low energy system complete with automatic controls that turn off lights when rooms are un-occupied or when adequate daylight is available.

This is also one of the first buildings to be fitted with waterless urinals, demonstrating the client's commitment to lowering the environmental footprint of their buildings and offering a demonstration of the best new conservation methods available.

Modern tools

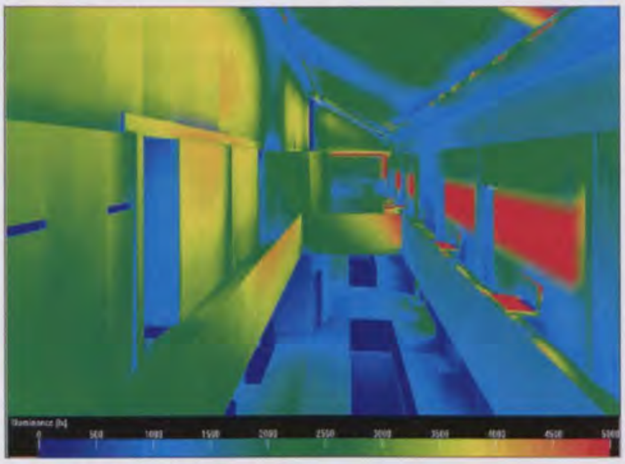
The CFD study used to analyse the complex air flow within the kitchens demonstrated the application of modern engineering techniques to this project. The project also took advantage of a number of other advanced, in-house engineering techniques to study the building.

The atrium daylight and the transfer of light between the atrium and surrounding rooms is a complex process that cannot be accurately studied with standard daylight analysis software. An advanced radiocity-based calculation method was used to fully account for the complex light reflectances through the depth of the atrium and to adjacent rooms.

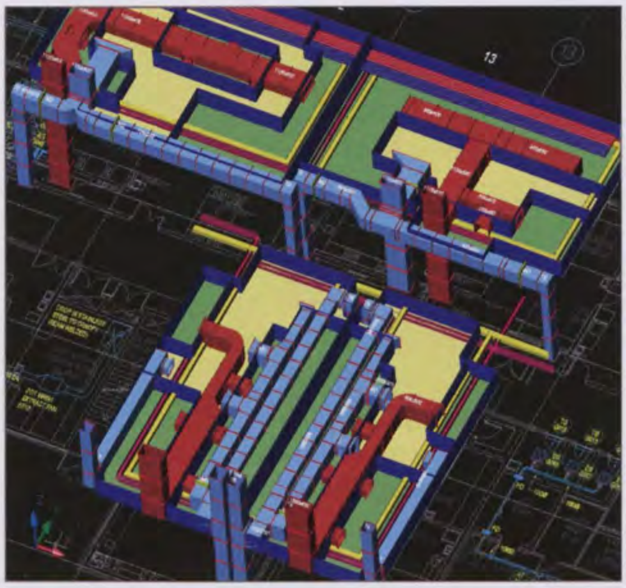
The following images show an early simulation model image of the atrium that was used to study glare and the associated light level results output.

The advanced daylight simulations were used at an early stage of the project to advise the project architect on the required glazing areas and distribution.

Radiocity study of solar glare in the atrium space.



Lux level results for the atrium space.



The natural ventilation and thermal mass interaction was studied through the use of a complete building dynamic simulation.

The project was run as a "paperless" project with almost no drawings printed and all communication carried out using a project email mailbox. While this paperless project technique is now commonly used, it was an innovative concept at the time of the projects design.

The project also adopted the use of BIM (Building Information Modelling) techniques to model the complex services layouts within the limited ceiling voids above the kitchens. This modelling allowed a number of complex co-ordination issues to be identified and resolved prior to construction.

Lessons offered

This building extends its teaching function beyond its primary purpose of a tourism and leisure building.

The building offers a useful case study on the use of passive design techniques that are optimised for an educational building. It also offers useful results for several new, innovative techniques such as the use of displacement ventilation in kitchens, the use of advanced catering equipment, the use of hybrid natural ventilation and complex controls in a high-usage catering facility. It is hoped that many of the lessons and results achieved can assist in the development of future low energy buildings of a similar nature.

It is also hoped that the provision of training in the use of low energy catering equipment will encourage the future chefs and managers who are trained in the building to invest in these low energy methods.

The building air tightness target and techniques were also a useful training exercise for the builders involved who gained the knowledge of how to produce future low energy buildings without additional costs.

All of the building's low energy techniques were achieved at **no additional capital cost** and are the result of genuine engineering techniques rather than expensive add on technologies.

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Lessons for the future

While the building was recently completed, it was designed over five years ago and the techniques used should be viewed in the context of this time scale as there have been considerable changes in technology over this period.

The building achieved grant funding from SEI for the incorporation of a number of additional energy conservation measures including the provision of heat recovery on the kitchen ventilation system which would have made an interesting additional case study. Unfortunately the grant funding was cancelled due to project delays (with the overall building funding) and the grant funding was removed, preventing the installation of the heat recovery.

While heat recovery is not traditionally assumed appropriate for kitchen systems due to concerns over exchanger fouling, an examination of the system fans after a year of intensive use (with no grease build up) indicates that the heat recovery system would have been successful if installed. A UV filtering proposal had been proposed as an additional heat exchanger protection mechanism as UV light can prevent grease build up.

An analysis was also carried out on the potential use of micro combined heat and power for the building as the building has a relatively large hot water load. At the time of design the calculations determined that a payback period in the order of 60 years would be achieved but in the last five years there have been considerable reductions in the cost of small CHP units and it is likely that the application of CHP to a building of this type might be attractive in current and future market conditions, offering notable additional energy savings.

The building's overall energy performance is set to consume less than half the energy consumed by a similar building constructed to good practice standards. The building offers a unique case study of the use of displacement kitchen ventilation in Irish conditions.

Appendix A

Performance metrics

Kitchen of the future:

The energy savings associated with the provision of the advanced, low energy catering equipment within the *"kitchen of the future"* were calculated as shown in the table below. The calculation took into account both the savings in energy consumption associated with the equipment and the associated reduction in space conditioning energy.

Per kitchen	
Energy saving (cooking and ventilation)	19,792 kWh/yr
Saving in CO_2 Emissions	3 Tonne / Year
Cost Saving	€3,202.58 per year

Kitchen displacement ventilation strategy

The use of the displacement ventilation strategy, compared with an alternative high level supply strategy was calculated to generate the following savings.

Energy saving	20,216 kWh/yr
Saving in CO_2 Emissions	16 Tonne / Year
Cost Saving	€2,670 per year
Additional cost	€40,814.78
Payback period	15 years

Lighting controls:

The use of low energy lighting and associated controls was calculated to result in an annual saving of approximately €9,000 and to have an additional cost of €65,000 which results in a payback period of 7.2 years.

It should be noted that at the time of design (five years ago) low energy lighting and controls was not commonly used and over the last five years the costs of same have dramatically reduced.

CHP:

An analysis of the use of CHP in the building showed that the system would have a 60 year payback period. Note that CHP engine prices have reduced considerably over the last five years and the payback period under current prices would be in the order of ten years.

Overall energy monitoring:

The building's monitoring system shows the combined heating and hot water energy usage during the first year of operation to be 158 kWh/m^2/yr which is a very impressive figure for a building of this type. A comparative building of this type would consume 217 kWh/m^2/yr according to the CIBSE good practice guidelines.

The monitoring also shows that hot water energy consumption was only 6% of the total heating energy use which is surprisingly low and that the kitchen fan energy was only 7% of the total electrical energy usage. This small fan energy usage supports the observations that the advanced controls strategy results in the fans often being run at low volumes and the natural ventilation and mixed mode option being used extensively.

The total water consumption of the building is 20m^3/day which is as expected.

Care must however be taken when viewing energy information from the first year of a building's operation and preliminary results can often be misleading as an indication of the long-term performance of a building of this type.

The electrical energy is monitored by several meters:

- Overall electrical
- Typical kitchen
- Kitchen plant energy

This monitoring information will prove very useful for future project design as very limited data exists on training kitchen energy usage in an Irish climate.

Initial teething problems existed with the electrical energy meters which were resolved half way through the year. For this reason full-year electrical energy information is not currently available but will be published later in the monitoring period.

Kitchen CFD testing

As the design of the displacement system relied heavily on the results of the CFD modelling it was important to test the completed kitchens and compare the results with the modelling.

A completed kitchen was applied with a known heat load and temperature measurements were taken at various locations in the kitchen, most importantly at an operator's position, at various heights.

The results were compared with the CFD model when applied with identical loads and the results were remarkably similar, showing that the use of CFD was a valid design method for the kitchen displacement systems.

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Control, Energy, Services, Design

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CIBSE SDAR* Awards

The Finalists 2011: Rory Burke, Colm Saul, Jonathan Tooth (JV Tierney), Declan Leonard, Michael F. Keohane (PMG), Marc Wegner (DIT Post Graduate).

The SDAR* Awards is an initiative by CIBSE Ireland, organised by the School of Electrical Engineering in DIT, supported by *bs news*, and sponsored by John Sisk & Son. SDAR stands for Sustainable Design & Applied Research and it applies to engineering of the built environment. It is different to other competitions in that it is intended to encourage applied research, disseminate knowledge gained from this research, and raise the level and quality of innovation in projects. Entries must critically evaluate what they are doing and examine, in a transparent way, mistakes as well as successes on innovative projects. In this way the profession builds capacity to innovate successfully, and moves from ideologically-driven projects sometimes offering poor value, to evidence-based innovations that provide proven value.

Entries for SDAR* Awards 2012 are due in soon

Abstracts of interesting or innovative projects in which there is data, analysis and evidence of success or failure are likely to be short listed.

One page abstracts are invited by **October 31st 2011** and should be submitted electronically to kevin.kelly@dit.ie by this date.

The five judges of the event in 2010 were all industry senior figures:

- **Alan Duggan**, Arup and Chairman CIBSE Ireland
- **Justin Keane**, John Sisk & Son and CIBSE
- **Brian Geraghty**. BGA Associates and CIBSE
- **Kevin O Rourke**, SEAI
- **Kevin Gaughan**, School of Electrical Engineering Systems DIT.

The event was organised by staff of the Department of Electrical Services Engineering in DIT as part of their parallel SDAR* research centre. *http://eleceng.dit.ie/sdar/*

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