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**AALBORG UNIVERSITY**  
DENMARK

## **Master's Thesis Ideas 2013**

*M.Sc. in Indoor Environmental and Energy Engineering*

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Aalborg University  
Department of Civil Engineering  
Indoor Environmental Engineering

**DCE Latest News No. 38**

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by

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May 2013

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## Diffuse ceiling inlet.

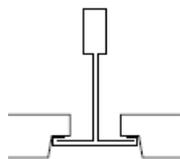
Diffuse ceiling inlet is an air distribution principle where the whole ceiling is the supply opening. It is often made by using the noise reducing ceiling as the supply opening. The air will enter the room through the very small slots everywhere between the batts and the support. Earlier experiments have shown that this air distribution system is very simple to design and that it can handle a very high thermal load. Widex new CO2 neutral administration building has used the principle based on experiments made at AAU. See the photos.



New experiment with the air distribution in high rooms indicates that the system in this case do not perform so well with respect to handling high loads. Furthermore the flow in the room took place as a sort of unsteady flow or a flow with more solutions. The experiments were made I a room with the height of 4.0 m and with a special supply geometry where the air is supplied though the whole painted surface.

## The project.

The aim of the project is to address the importance of different supply geometry as e.g. small slots or whole surface openings, and to study the importance of room height.



Small slots in the ceiling



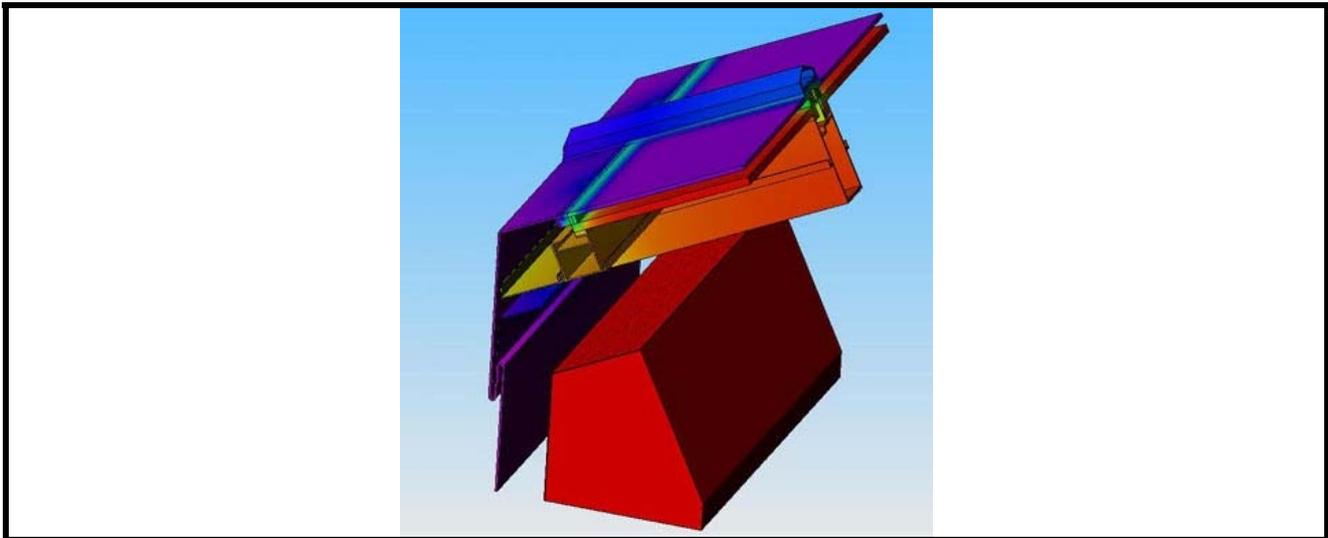
Supply through the painted surface

The next part is to study why unsteady flow may take place in some situations depending on the geometry of load and the distribution of the openings. Finally a design guide book should be developed for the air distribution system.

The work will be based on full scale experiments and CFD predictions.

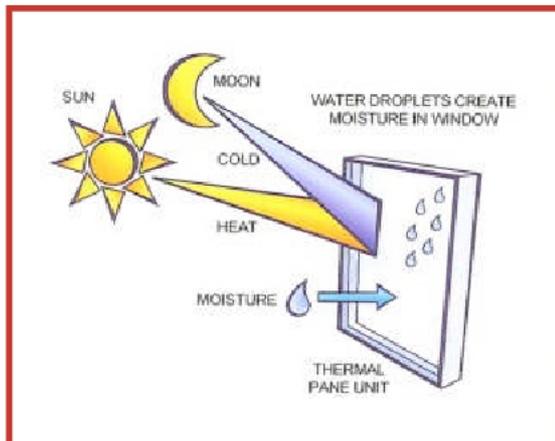
Li Liu, Peter V. Nielsen and Rasmus L Jensen will be supervisors.

# Master project proposal



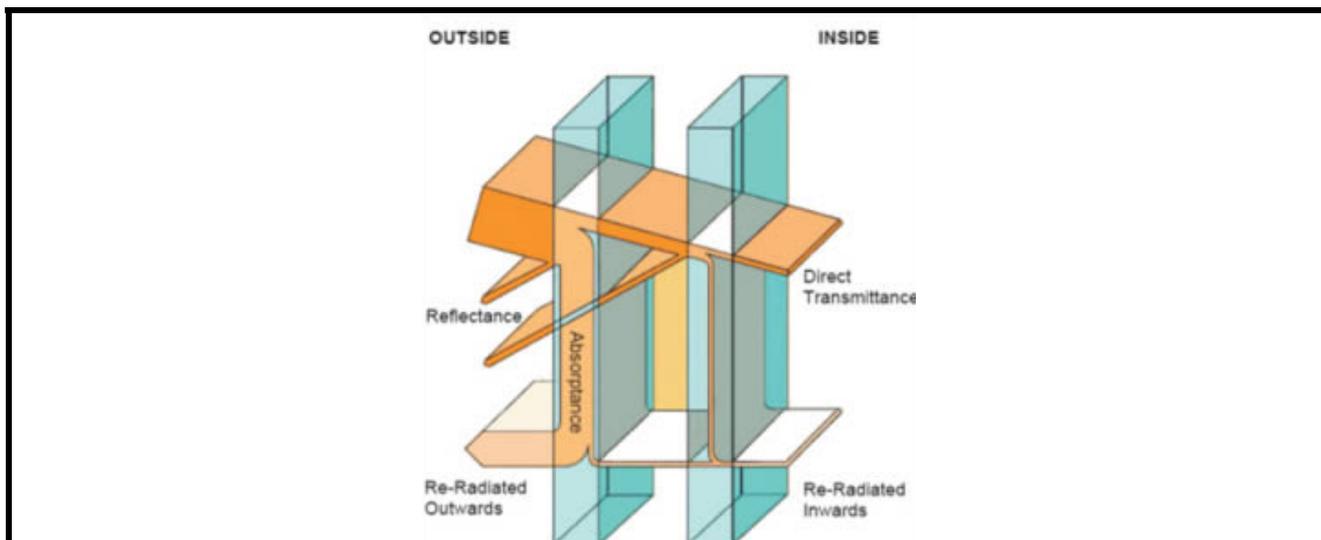
<p>● Name</p>	<p><b>3D thermal simulation of roof windows</b></p>
<p>● Background</p>	<p>Windows are part of every building envelope and contribute to heat loss of buildings. The thermal transmittance of windows can be either tested or simulated. The thermal testing of windows is a long and expensive process and therefore the thermal performance simulation has large potential in the development process when a quick and inexpensive evaluation is needed.</p>
<p>● Purpose and aim</p>	<p>Nowadays the simulations are 2D, however windows are 3D elements and therefore it is of importance to investigate if 3D thermal simulations of windows can be used for the purpose of product development and if there is a benefit of using 3D compared to 2D simulations.</p>
<p>● Methods</p>	<ul style="list-style-type: none"> <li>- Research of current software possibilities for 3D thermal simulations.</li> <li>- Comparison of accuracy and reliability of 2D and 3D thermal simulations.</li> <li>- 3D simulations vs. real thermal measurements of window in guarded hot box.</li> </ul>
<p>● VELUX support</p>	<ul style="list-style-type: none"> <li>- Test parts</li> <li>- Test laboratory</li> <li>- Supervision/consultancy</li> </ul>
<p>● Scope and duration</p>	<ul style="list-style-type: none"> <li>- Final MSc project</li> <li>- 6 months</li> </ul>
<p>● Contact person</p>	<p>Kristian Ørnsvig Nielsen <a href="mailto:kristian.oernsvig@velux.com">kristian.oernsvig@velux.com</a>          David Appelfeld <a href="mailto:david.appelfeld@velux.com">david.appelfeld@velux.com</a></p>
<p>● Department location</p>	<p>Industrivej 22, 8752 Østbirk</p>

# Master project proposal



<p>● Name</p>	<p><b>Design criteria for moisture</b></p>
<p>● Background</p>	<p>Establishment of knowledge as the basis for preparing design criteria of wood and PU VELUX windows without critical moisture load as a consequence of air humidity and external water exposure so that the construction is designed with the best life conditions.</p>
<p>● Purpose and aim</p>	<p>Analysis, calculation and test of moisture absorption and migration of moisture through wood and PU construction with a view to stating design criteria for placement of moisture barriers (moisture resistant materials) or dimensioning of ventilation/dehumidification possibilities under relevant environmental influences in the use situation. The analysis must clarify influences acting from the inside considering different external environments (season, air humidity, temperature, precipitation etc.) Including a description of condensation, isotherms/dew point, steam pressure etc.</p>
<p>● Methods</p>	<ul style="list-style-type: none"> <li>- Literature study on available methods.</li> <li>- Application of theoretical knowledge into practice.</li> <li>- Validation of calculations by real measurements during field test.</li> </ul>
<p>● VELUX support</p>	<ul style="list-style-type: none"> <li>- Test parts</li> <li>- Test laboratory</li> <li>- Supervision/consultancy</li> </ul>
<p>● Scope and duration</p>	<ul style="list-style-type: none"> <li>- Final MSc project</li> <li>- 6 months</li> </ul>
<p>● Contact person</p>	<p>Kristian Ørnsvig Nielsen <a href="mailto:kristian.ornsvig@velux.com">kristian.ornsvig@velux.com</a>          Mobil: 24 28 35 68          David Appelfeld <a href="mailto:david.appelfeld@velux.com">david.appelfeld@velux.com</a></p>
<p>● Department location</p>	<p>Product Technology &amp; Materials          Industrivej 22, 8752 Østbirk</p>

# Master project proposal

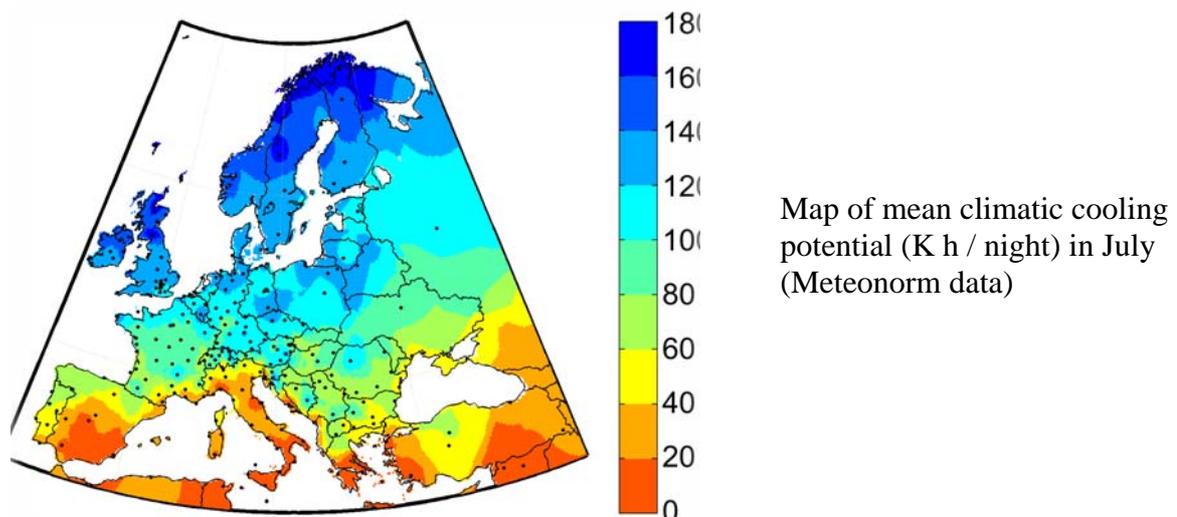


<p>● Name</p>	<p><b>Temperature transfer through window construction under dynamic outdoor boundary conditions</b></p>
<p>● Background</p>	<p>Windows are part of external building envelope and they are exposed to a dynamic solar radiation and diverse weather conditions. These factors influence the temperature of window construction which consequently has an impact on thermal transmittance of window moisture content within a window construction and temperature comfort within a room.</p>
<p>● Purpose and aim</p>	<p>The purpose of the project is to investigate what are the temperatures within a window construction under dynamic solar radiation and how the temperatures can be correctly calculated. The investigation has to be performed under different boundary conditions, e.g. during winter and summer and in different climatic zones, e.g. Copenhagen, Prague, Rome.</p>
<p>● Methods</p>	<ul style="list-style-type: none"> <li>- Literature study on available calculation methods.</li> <li>- Development of calculation model.</li> <li>- Application of theoretical knowledge into practice.</li> <li>- Validation of temperature calculations through real temperature measurements during field test.</li> </ul>
<p>● VELUX support</p>	<ul style="list-style-type: none"> <li>- Test parts</li> <li>- Test laboratory</li> <li>- Supervision/consultancy</li> </ul>
<p>● Scope and duration</p>	<ul style="list-style-type: none"> <li>- Final MSc project</li> <li>- 6 months</li> </ul>
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<p>● Department location</p>	<p>Industrivej 22, 8752 Østbirk</p>

## Ventilative Cooling of Residences

The current development in building energy efficiency towards nearly-zero energy buildings represents a number of new challenges to building design and construction. One of the major challenges is the increased need for cooling present in these highly insulated and airtight buildings, which is not only present in the summer period but also in the shoulder seasons. In most post-occupancy studies of high performance buildings in European countries elevated temperature levels is the most reported problem, especially in residences. Designers underestimate the cooling need and often use too simplified design methodologies to assess the risk of overheating.

Ventilation can be an attractive and energy efficient solution, as it is already present in most buildings and because it can both remove excess heat gains as well as increase air velocities and thereby widen the thermal comfort range. As cooling becomes a need almost all year around the possibilities of utilizing the free cooling potential of low temperature outdoor air increases considerably. This leads to the following scope for the project: “How and when can strategies for increased ventilation reduce the cooling load while maintaining good environmental quality?”



Energy efficient use of ventilative cooling (air-borne systems) in high performance buildings face several challenges to become the preferred solution. This leads to the following topics that could be included in the project:

- Mapping of existing ventilation systems and technologies, and typical comfort control solutions.
- Analyse ventilative cooling systems from the perspective of utilization of the free cooling potential of outdoor air assisted by other natural sinks, exploitation of the building thermal mass and other passive cooling measures using thermal building simulation and CFD.
- Development of new methodologies and tools for prediction of ventilative cooling performance and overheating risk suitable for design purposes as well as for integration in energy performance calculation methods (BE10).

- Development of new ventilative cooling strategies for nearly zero energy houses as well as advanced control strategies providing optimal cooling (optimise energy efficiency) and comfort.

Project partners: Velux A/S

Supervisor: Per Heiselberg, Michal Pomianowski

## Dynamiske facader: Energi- og indeklimamæssige potentialer

### Baggrund

Fremtidens facader er dynamiske og har egenskaber der giver mulighed for at facadens energibalance kontrolleres ved hjælp af facadens dynamiske teknologier. Teknologierne omfatter

- dynamisk solafskærmning
- dynamisk isolering af facadeelementer
- sikring af frisk luft til bygningen (øget anvendelse af naturlig ventilation)
- bedre styring af dagslysadgang til bygningen
- kontrol af lyd dæmpning
- lagring af termisk masse
- reducere af behov for elektrisk belysning.

Et af koncepterne der muliggør denne styring er konceptet *Energy Frames*.

Ved anvendelse af dynamiske facadeteknologier i kombination med beskrivelsen af den ønskede styring af disse teknologier, opstår et behov for kendskab til teknologiens egenskaber under forskellige stadier/udformninger.

I relation til videreudviklingen af fremtidens dynamiske facade teknologier, ønskes der udført analyser af teknologiernes ydeevne og potentiale.



### Metode

Dette projekt har fokus på isolerende elementer, og skal belyse: - Hvilken tæthed der kan opnås, - hvilken isoleringsevne der opnås for det samlede system samt - mulige kombinationer med andre funktioner: solafskærmning, ventilation.

Gennem anvendelsen af fuldskalaforsøg under kontrollerede forhold undersøges teknologiens ydeevne til at kunne kontrollere den termiske transport ved anvendelse af hot-box forsøg. Herved fremskaffes data for den energimæssige ydeevne af hele facadeelementet. På tilsvarende vis kan der opnås en indsigt i teknologiernes afskærmningsmæssige og optiske egenskaber ved forsøg med kunstig sol for dermed at kunne kortlægge egenskaberne ved kortbølget og langbølget stråling.



### Resultat

Forsøgsresultaterne skal danne grundlag for (videre-) udvikling af beregningsmodeller til analyse og dokumentation af ydeevnen, såvel som aktiv regulering af det endelige facade produkt under EnergyFrames.

### Projektpartnere

ProTec Vinduer / Inwido Denmark A/S, Rambøll A/S, SBI-AAU

### Supervisere

## Dynamiske facader: Intelligent styring og brugerinteraktion

### Baggrund

Fremtidens facader er dynamiske og har egenskaber der giver mulighed for at facadens energibalance kontrolleres ved hjælp af facadens dynamiske teknologier. Teknologierne omfatter

- dynamisk solafskærmning
- dynamisk isolering af facadeelementer
- sikring af frisk luft til bygningen (øget anvendelse af naturlig ventilation)
- bedre styring af dagslysadgang til bygningen
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Et af koncepterne der muliggør denne styring er konceptet *Energy Frames*.

Ved anvendelse af dynamiske facadeteknologier i kombination med beskrivelsen af den ønskede styring af disse teknologier, opstår et behov for kendskab til teknologiens egenskaber under forskellige stadier/udformninger. Elementer med flere funktioner giver flere muligheder for både at kunne tilfredsstille indeklimabehov og energikrav, men dette stiller også større krav til de mulige styrings- og reguleringsfunktioner.



I relation til videreudviklingen af fremtidens dynamiske facade teknologier, ønskes der udført analyser af teknologiernes ydeevne og potentiale.

### Metode

Dette projekt har fokus på styringen af den dynamiske facade, og skal afdække hvordan brugerne i praksis vil interagere med systemet, i hvilken grad den automatiske regulering kan accepteres, og hvor ofte brugerne ønsker at overstyre automatikken.

Afprøvningen af det automatiske styresystem vil ske i demonstrationsbygninger, med to forskellige styringsstrategier: en simpel og en mere avanceret. Undersøgelsen planlægges i samarbejde med styringsfabrikant og med bygherre/bygningsejer og vil både omfatte målinger og registreringer af styringen samt interviews/spørgeskemaer med brugerne. Herved fremskaffes et bedre grundlag for udvikling af realistiske styringsstrategier, som brugerne vil acceptere.



### Resultat

Forsøgsresultaterne skal danne grundlag for (videre-) udvikling af realistiske styringsmodeller til analyse og dokumentation af ydeevnen, såvel som aktiv regulering af det endelige facade produkt under EnergyFrames.

### Projektpartnere

ProTec Vinduer / Inwido Denmark A/S, Styringsfabrikant, Rambøll A/S, SBI-AAU

### Supervisere

En mulig demonstrationsbygning vil være Rigshospitalets midlertidige pavillonbygning, men flere andre bygninger vil også være mulige, både boliger og institutioner.

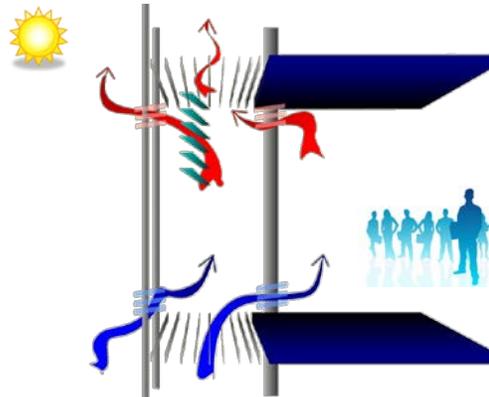


## Midlertidig pavillon i 6 etager

En midlertidig pavillon på 6 etager skal genhuse funktionerne i den gamle røde H-bygning, Opgang 51. Byggearbejderne igangsættes marts 2013, og pavillonen skal være klar til ibrugtagning ved årsskiftet 2013 - 2014

## Air recirculation in Double-Skin Facade

Double-Skin Façade (DSF) is an expensive and acknowledged solution between the architects. One of the most appreciated properties of such façade is acoustical benefits it can provide in noise polluted areas and the protection it offers to motorized solar shading devices. Though, the double-skin facades are also known because of the challenges present in estimation of energy transport and air flow in such constructions.



Some of the studies have developed a hypothesis of existing recirculation flow in the upper part of DSF cavity. Several experimental results confirm that possibility. In this project, it is of key importance to verify and document the hypothesis or to prove its non-existence. It can be done in several ways:

- Experimental full-scale studies
- Experimental scale models
- CFD...

The challenge is to define when and why the flow recirculation can take place. It is expected to be very unstable phenomenon (no steady state condition can be reached), it grows and collapses in a periodic manner. This is one of the reasons why it is necessary to be able to visualize it. The presence of flow recirculation will normally have an impact on the convective heat transfer, and therefore on the complete energy performance of the building.

There is no visualization technique developed for such type of measurement, this can be another research question.

## Developing high resolution load profiles for household energy use from time-use data

According to the 2012 Danish energy agreement, improving energy efficiency and managing intermittent energy are both crucial for increasing Denmark's share of renewable energy. Although, much has been done to increase the energy efficiency of buildings, results from demonstration projects on low-energy buildings show that there is a great need for better understanding of the user behaviour in order to fully tap the existing potential of the building sector. Balancing intermittent energy production is not only dependent on efficiency improvements but also on accommodating consumption patterns and energy storage in buildings. Hence, ensuring efficiency and flexibility calls for taking the user-dependent energy use under the microscope. Otherwise the gap between actual and expected energy performance of buildings will persist.

Energy use in the home is highly dependent on the activities of the residents. More specifically, the timing of energy use, particularly electricity, is highly dependent on the timing of the occupants' activities. Thus, in order to model domestic demand profiles with high temporal resolution, for example, in the context of designing and assessing demand side management systems (including the time-shifting of demand), it is of great benefit to take account of residents' behaviour in terms of when they are likely to be using household appliances and lighting.

Time-use data, describing in detail the everyday life of household members as high-resolved activity sequences, have a largely unrealized potential of contributing to domestic energy demand modelling. Therefore, the aim of this project will be to develop a method/tool to generate high resolution load profiles for household energy use from detailed data set on the time use for everyday activities in Danish households delivered by DDA, and validation of the model with recent measurements of household energy use from Komforthusene project.

The study will be divided into 3 phases. The first phase will be focused on conversion of activity data to energy load profiles. The second phase will be dedicated to model development. In the last phase the validation of the model with measurement of energy use will be done.

The second phase, the development of the model, could be performed in collaboration with Uppsala University and/or Linköping University.

# Modelling of user behavior and its impact on building energy use

The current development in building energy efficiency towards nearly-zero energy buildings represents a number of new challenges to building design and construction.

It is well documented that different users living in completely identical buildings can have levels of energy consumption varying with several hundred percent. It is also documented that these differences only to a limited extent can be explained by well-established consumer categories as socio-economic variables or lifestyle groups. Furthermore, when new efficient technologies are taken into use, the predicted and calculated energy savings are most often not reached. This may be because the calculations are based on erroneous assumptions regarding user behavior, because the users do not value the new technologies or because the new technologies effects expectations of comfort norms among the users. Within a techno-economic approach this last issue is known as the rebound effect, where energy savings are invested in higher comfort and within a socio-technical approach this is taken even further to show how new norms of comfort continually have risen together with the development of new technical possibilities and efficient technologies.

Within technical sciences there is a growing awareness and interest in different ways of understanding users and their interaction with technologies as numerous research projects has shown, that the choice and operation of technologies in dwellings affects occupant's behavior, energy use and indoor environment. One example is the type of thermostat used for heating, which affects duration of heating periods, heating setpoint temperatures during day and night and risk of overheating. Another example is the type of ventilation system, whose operation is not understood by the occupants, and which affects window opening behavior.

Recently, the growing awareness has been seen also in the different approaches of making models including impact of user behavior, which can either be used for better predicting energy consumption, or for optimizing technologies in the design phase. The main purpose of the project is to develop new models for user behaviour in residences, which can be used for more realistic predictions of energy use in new buildings and/or energy saving potentials in building renovation. New models should be relevant also for use in relation to the EPBD regulations.

The starting point for the development can be one or more of the following approaches:

- **Psychological models** of occupant behavior can be grouped into those explaining the behavior itself and those related to the energy use in buildings.
- **Average value models** use the important parameters for occupant behavior which influences the total energy use of a building for a selected period (e.g. daily, weekly, or monthly basis).
- **Deterministic models** use predefined typologies of families, which give deterministic input values for computer simulations.
- **Probabilistic models** use parameters and equations to evaluate the probability of an action or state.
- **Agent based models** model occupants as individuals, with autonomous decisions based on rules and experiences (e.g. memory, self-learning).
- **Action based models** define "occupant behaviors" as actions — *movement* and *control action* — that change the state of objects (movement is the change of occupant location, control actions are the operation state change of windows, lights, air-conditioners, etc.), propose a uniform description for occupant movement and control actions respectively, and classify each action by several typical patterns that can be easily investigated and applied to evaluate the impact of occupant behaviors on building systems.

Supervisor: Per Heiselberg, Henrik Brohus

## Investigation of building flexibility for shifting energy loads

According to the 2012 Danish energy agreement, by 2035 electricity and heating shall be based on renewable energy, and by 2050 this will be the case for the entire Danish energy system including transportation. However, this cannot be achieved only by decreasing the energy use and increasing the share of renewable energy sources. A crucial parameter for success of the stated goals is the flexibility of consumption side of energy system to balance intermittent energy production, see Fig 1.

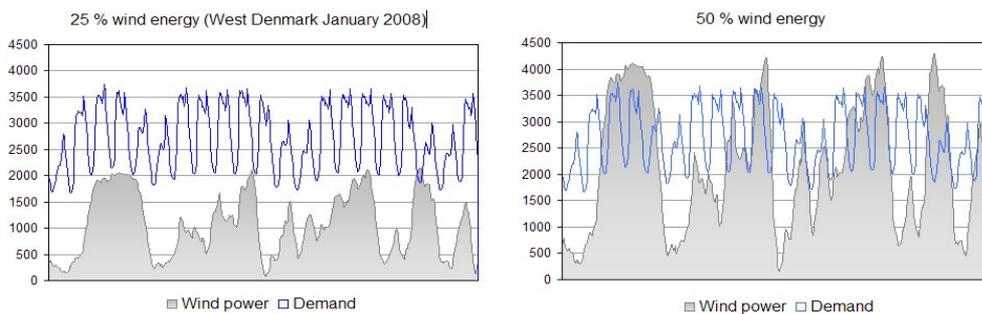


Figure 1: Wind production and energy demand in 2008 and 2020 [source: SØJ, DTI]

Around 30% of the consumption side is the building sector, which has a very clear and fixed daily load profile with morning and afternoon peaks during the weekdays and more event distribution during weekends,. Moreover, the energy demand profiles of our homes is a sum of many single components, which used smartly can contribute in shaping the load profiles so it fits better to future energy production profile see Fig.2

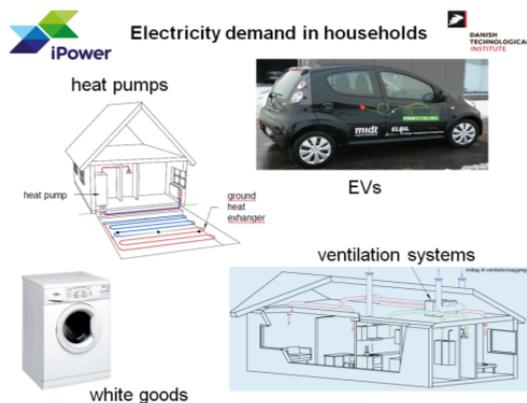


Figure 2: Components of energy demand in households [source: SØJ, DTI]

Therefore, the aim of this project will be to investigate the flexibility potential for storing and shifting energy loads of the buildings. The study will include dynamic building simulations in order to verify and quantify the flexibility potential of different buildings' components, i.e. construction and HVAC systems. Moreover, the study will analyse different control strategies for potential activation.

## Investigation of heat transfer coefficient and development of deck finish located behind diffuse ceiling supply

The aim of this project is to support decision making for PSO PhD project titled “Natural cooling and ventilation through diffuse ceiling supply and thermally activated building constructions”. The aim of the PhD project is to develop a natural cooling and ventilation system for office buildings. Nowadays, office buildings are very well insulated and very tight what together with high internal and external heat loads can often result in the whole year cooling requirements. Aalborg University has developed a new diffuse ceiling supply system through suspended ceiling which allows providing air with very low temperatures without risk of drought. The system will also take advantage of the high thermal mass and thermally activated system integrated in the prefabricated concrete deck elements located behind the suspended ceiling. The thermally activated system will be activated both for heating and cooling in some periods of the year and depending on system requirements. For example, the system will operate in heating mode for some days in the year when internal and external heating gains will not cover heat losses and will operate in cooling mode during the days when natural cooling will not be available because of the high outdoor temperatures. What is more, for some of the days in the year the air in the room might be re-circulated from the room to the plenum above the suspended ceiling and back to the room to cool or heat the room. In these days, heavy thermally activated ceiling will act as heating/cooling buffer to help maintain good indoor thermal comfort in the room.

However, the thermal mass and thermally activated system in the deck will be hidden behind the diffuse ceiling which to some extent will limit heat transfer (especially radiant part) between the ceiling and the rest of the room. In that case, the heat transfer might mostly rely on convective heat transfer which for that reason need to be enhanced in order to optimize the whole energy system performance. Therefore, the aim of this study will be to investigate convective heat transfer for various velocities and different finish of the ceiling surface. The investigation will include CFD simulations and experimental test. The CFD modeling will be used to study different ceiling surfaces but also to support design of small scale test chamber which will be used to conduct and compare energy performance of different ceiling finishes.

The result of the research should indicate appreciable velocities in the plenum and correlations between air change rate in the plenum and convective heat transfer coefficient on the surface of the decks. What is more, the investigation should highlight how, with what materials and to what extent ceiling surfaces should be extended in order to enhance heat transfer coefficient on the bottom surface of the decks. These information will be then after used for the final design of the prototype decks located behind the suspended ceiling.

## Investigation of different evaporative cooling potential in European climatic condition

From the energy point of view, passive cooling technologies should be considered first from mechanical cooling to ensure low energy use for cooling in buildings. However, climatic potential for passive cooling such as, for example, night time ventilation or natural ventilation might be found insufficient in areas where temperatures are high and hot seasons are long.

Therefore, in these warm locations mechanical cooling (refrigerant cooling) is often chosen without taking into account the passive solutions. Nevertheless, to reach comfort in the buildings mechanical cooling (refrigerant cooling) should be always the last option that should cover only the very warm climatic areas. The evaporative cooling systems represent the compromise between mechanical and passive cooling systems and can be used in the areas where mechanical cooling is not necessary and where passive cooling reliability is not sufficient. Moreover, evaporative cooling has many advantages, such as, lower energy consumption (especially during peak hours) than mechanical cooling, it is simple and cheap in construction, use water instead of refrigerants. What is more, evaporative cooling helps to keep air clean, free of dust and dirt.

The focus of this project will be to define climatic cooling potential for evaporative cooling systems in Europe. The usage of this type of systems depends on the wet bulb temperature, and depending of this temperature, choice would be made between direct evaporative cooling (DEC) and indirect evaporative cooling (IEC). In addition, in climates with higher wet bulb temperatures and higher humidity, systems can be supported with desiccant wheel (DW). Furthermore, the combination of the systems could increase feasibility and operational range of evaporative cooling. The result of this part of the project could be a map indicating in which region which system/combination of systems would be recommended to meet comfort in the building.

The study will include numerical/experimental performance analysis of various evaporative cooling systems such as, direct evaporative system, indirect evaporative system, desiccant wheel and combination of these under various climatic conditions. The aim of the project is to define the most energy efficient and sufficient configuration of evaporative cooling system that could at the same time reach comfort in buildings under certain European climatic conditions.

For the experimental part, students will be involved not only in the measurements of the energy performance of different system configuration but also in the development of the experimental set-up itself.

