H.F.R.I.
Hellenic Foundation for Research & Innovation

Innovative modelling techniques to determine thermal comfort and the demand response of Nearly Zero Energy Buildings

MoTher-CoRe

1st Call for H.F.R.I. Research Projects to Support Faculty Members & Researchers and Procure High-Value Research Equipment

MOTHER-CORE
COMFORT IN NZEBS

Title of the research project:	**Innovative modelling techniques to determine thermal comfort and the demand response of Nearly Zero Energy Buildings – MoTher-CoRe**
Principal Investigator:	**Professor Agis M. Papadolos**
Reader-friendly title:	**MoTher-Core**
Scientific Area:	**Environment & Energy**
Institution and Country:	**School of Mechanical Engineering, Aristotle University of Thessaloniki, Greece**
Host Institution:	**Aristotle University of Thessaloniki**
Collaborating Institution(s):	**1. Technical University of Crete 2. Karlsruhe Institute for Technology**
Budget:	**169.702,50€**
Duration:	**36 Months**

H.F.R.I.
Hellenic Foundation for Research & Innovation

Research Project Synopsis

Main goal of the project is:
"The development of an integrated methodological approach for determining the thermophysical profile of the indoor environment, taking into account innovative development models and advanced sensors"

Such a **methodological** approach can contribute to a more detailed description of the thermal comfort conditions and to a more accurate recording of the thermal loads of the construction, which is a necessary for determining and checking the performance of the buildings.

In particular, the **implementation** of this program will lead to the determination of the relationship between flexibility measurements and thermal comfort indicators as well as the identification of parameters that can ultimately contribute to both real-time monitoring of the built-in performance capabilities of the construction (building's mass thermal charge) as well as thermal comfort. All these parameters will allow the identification, design, development and evaluation of advanced sensors, which enable the improved determination of the thermal profile of the internal environment of structures.

In addition, **innovative techniques** that utilize and contribute to the further processing of the information collected by the sensors will be developed, leading to the complete thermal description of the internal environment of the construction. This approach will contribute to the development of **advanced stochastic control techniques** that maximize and maintain the built-in efficiency of buildings and their energy systems, improving thermal comfort and thus contributing to the development of the concept of interactive construction, including environmental and energy parameters.

Project originality [1/2]

The problems where this research project focuses on are:

1. **The performance of conventional temperature sensors**
   - The use of **conventional air temperature sensors** showσ **problems and gaps,** as the thermal protection of buildings steadily and rapidly increases and the use of low temperature, underfloor heating and chilled roof systems gets more extensive. Hence, thermal comfort is achieved more and more by utilizing the indoor **radiant temperature** and **not the air temperature**. Especially regarding radiant heating-cooling systems, air temperature sensors have proven to be insufficient in the efficient regulation of their operation and unable to capitalize on their advantages in providing thermal comfort and energy savings.
   - Single node air temperature sensors lead to a **partial display of the energy models of buildings** and contribute to the efficiency gap of the buildings. These models assume a homogeneous air temperature in thermal zones while single node air temperature sensors fail to represent the spatial averages of thermal conditions in these spaces.
   - In **contrast**, sensors (or sensor networks) based on operative temperature that is considered the best environmental index of thermal comfort and most thermal comfort standards are based on it
   - Given the expected energy refurbishment of the building stock in Europe, *such an accuracy in measuring thermal comfort conditions can prove crucial in objectively setting reference sizes for Measurement and Verification in the form of Reactive Energy Contracts.*

Project originality [2/2]

The problems where this research project focuses on are:

2. The perception of comfort by the occupants

- In the objective determination of thermal comfort, the perception of heating by the occupants of the buildings is a factor to be further explored within the research project. Recent researches show that the combination of real-time thermophysical parameters measurements by innovative sensors must be combined with thermal comfort information from the occupants themselves. *This approach can highlight the appropriate subjective factors (eg social, psychological) that influence the behavior of occupants regarding the operation of the building systems. In this way, suitable conditions of thermal comfort and optimal energy behavior of the building can be achieved with maximum efficiency.*

Innovation of this project is the fact that the *use of advanced operative temperature sensors my not directly address the three areas of interest (thermal behavior of buildings, air quality and thermal comfort), but can offer valuable information that in combination with other solutions and techniques can lead to better and more representative characterization of the internal built environment as a whole.*

Expected results & Research Project Impact [1/2]

1. Scientific impact

The outcomes of the research project will provide new insights in the science of thermal comfort and expand the knowledge in the thermal characterisation of indoor built environments. Combined with studies of occupants' behaviour the research project can generate multiple fields of research in the respective area that can lead to a better understanding of the interactions between thermal comfort perception by occupants, thermal behaviour of buildings and energy consumption of building energy systems.

2. Social Impact

- The more accurate characterisation of thermal comfort conditions in indoor built environments has a direct impact on the **wellbeing of all occupants** which is also defined as significant criteria in Environmental Rating Systems such as BREEAM and LEED. However, there is a particular aspect of the research project with direct influence on gender differences in the perception of thermal comfort in buildings.
- Advancements in **BEMS, ICT and sensoring equipment** with introduction of dashboards and other visualisation techniques offer the opportunity to promote better knowledge and handling of energy and comfort related issues to both genders and all ages in the built environment.

Expected results & Research Project Impact [2/2]

3. Economic impact

- The successful implementation of the research project can have a huge economic impact since the market for **comfort, indoor environmental and air quality** (IEAQ) sensors is growing rapidly, due to both the energy retrofitting of existing buildings and the construction of new, smart and interconnected buildings. Thermal comfort is a growing issue in all indoor built environments. To name an indicative example, as recently published data show, office building temperatures are usually set to ultimately satisfy the minority of their occupants.
- The increased construction activity across Europe, especially in retrofits of old buildings, will drive the IEAQ sensors market to grow significantly in the ongoing decade. The energy savings these devices offer will further drive their sales globally. The respective revenue from those sensors is expected to grow from $4.2 billion in 2015 to $7.1 billion by 2024 at a compound annual growth rate (CAGR) of 6.1%.
- Advanced sensors are playing a pivotal role in this market because these devices capture, communicate, and (in some situations) analyze crucial energy and operational data. For interconnected buildings, the global advanced sensor revenue is expected to grow from $1,160.3 million in 2016 to $3,221.9 million in 2025 at a 12.0% compound annual growth rate [19].

The importance of this funding

Through H.F.R.I research program, our research team was given the opportunity to **continue its research** on an important topic within the broader **environment and energy** field**,** with great research interest both considering the theoretical background and its practical application.

The **findings** of the research will significantly contribute to the improvement of the indoor environment conditions and the energy performance of building, since they will give occupants the chance to experience ideal indoor conditions without lower energy requirements and hence a smaller environmental impact.

The **implementation** of the above goal could not be achieved without:

1. The participation of:
   - young researchers, who after their Integrated Master are eager to further work on those topics
   - postdoctoral researchers, who after having completed their specialization, can contribute with their knowledge and expertise, to the better organization and faster development of research, and
   - experienced researchers and professors from three different universities (in Greece and Germany), who act as mentors, contributing their knowledge to the development of research as well as to its extroversion.

H.F.R.I.
Hellenic Foundation for Research & Innovation

COMMUNICATION

Building D, 8th Floor,
Process Equipment Design Laboratory
Scholl of Mechanical Engineering
Aristotle University of Thessaloniki
54124,, Greece
+30 231 099 6015, 6087
agis@auth.gr
www.pedl.meng.auth.gr

185 Syggrou Ave. & 2 Sardeon St. 2
171 21, N. Smyrni, Greece
+30 210 64 12 410, 420
communication@elidek.gr
www.elidek.gr