IMPROVED INDOOR ENVIRONMENT WITH NEW TECHNOLOGY

Andy Drysdale
Danish Technological Institute

Micro Structure Workshop

Tuesday 9 May 2006

MSW 2006

Agenda

- The MONTIE initiative – an introduction and a little background
- Activities and summary of results so far
  - The benefits of improved indoor environment (IAQ)
  - The link between IAQ, HVAC (Heating, Ventilation and A/C) and sensors
  - More about sensors for better IAQ
- Barriers and challenges

The aim of this presentation is to give an overview of the MONTIE initiative, and present its current status

....and to inspire innovative thoughts for possible new applications for (MEMS) sensors!

What is the MONTIE initiative?

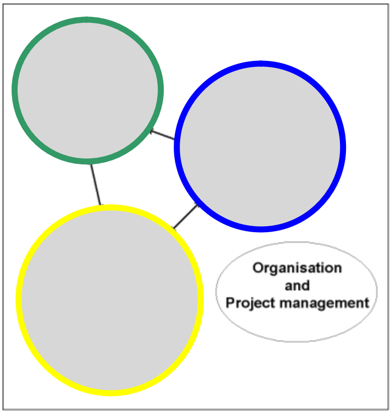
Multi-sensors and **O**ther **N**ew **T**echnology for **I**mproved indoor **E**nvironment in buildings

- A consortium of Nordic partners
- Funding from the Nordic Innovation Centre 2004 - 2006
- Increase focus on Indoor Air Quality (IAQ). Spread knowledge about its importance
- Address the current, and future uses, of advanced multi-sensors
- Technological developments to support improved HVAC systems
- Convert expert academic knowledge into practical applications and use.

The partners in MONTIE

- Danfoss A/S (DK)
- Hök Instrument AB (SE)
- Infineon Technologies SensoNor A/S (NO)
- The Finnish Association of HVAC Societies (FINVAC) (FIN)
- Finnish Society of Indoor Air Quality and Climate (FiSIAQ) (FIN)
- SINTEF IKT (NO)
- The Technical University of Denmark International Centre for Indoor Environment and Energy (DK)
- Danish Technological Institute (DK)
- Nordic Innovation Centre

What are the goals of the MONTIE initiative?



Main activities

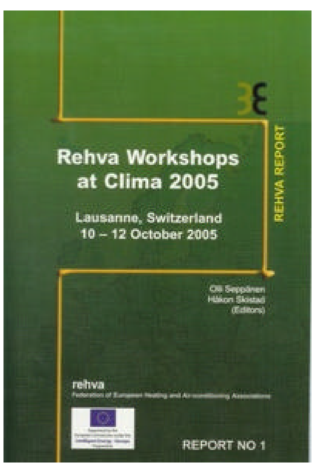
Information dissemination about:

- The importance of IAQ
- The advantages gained from using micro-sensors and other new technology

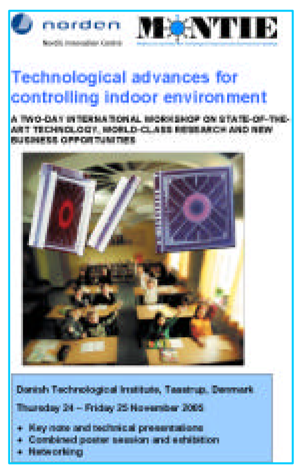
Increased information/awareness will

- Initiate coherent efforts to increase the level of knowledge about IAQ
- Initiate and boost the number of IAQ – and IAQ related - development activities
- Increase business and commercial export opportunities

Main activities so far



www.rehva.com/workshops/index.html



www.teknologisk.dk/montie

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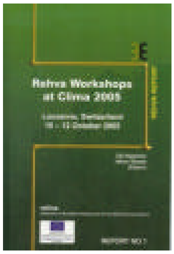
Main activities so far



Clima 2005

- Key-note and short presentations, poster sessions and workshops on scientific trends and practical developments in HVAC technologies
- Included a MONTIE workshop presenting MONTIE ideas and ambitions

MONTIE workshop programme

- Summaries of state-of-the-art (Nordic) technology on sensors
- Applications of these sensors for the measurement and demand based control of IAQ
- Discussion forum (more than 40 participants) to discusses the future needs for development and dissemination.

www.rehva.com/workshops/index.html

Technological advances for controlling indoor environment

- Focus on "State-of-the-art" technology. Key-note presentations on user-driven issues and invited presentations on technology-driven issues.

Programme

- IAQ, sensors and measurements, wireless communication and other new technology
- Intelligent HVAC installations and installation technology, including the use of sensors and coupling with security aspects
- New business opportunities and challenges
- Innovative solutions

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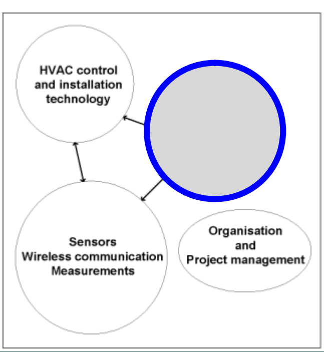
THE BENEFITS OF IMPROVED INDOOR ENVIRONMENT



AIR QUALITY
THERMAL
(ACOUSTIC)
(LIGHT)

The benefits of improved indoor environment (IAQ)

The importance of indoor air quality (IAQ) in buildings is indisputable.

People spend about 90% of their time indoors (at work, at home, transport)

Intake for a person per day:
- 1 kg food
- 2 kg liquid
- **15** kg air

Comfort-Productivity costs:

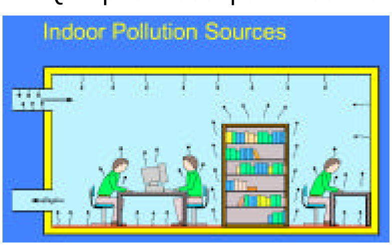
People	100
Maintenance	10
Financing	10
Energy	1

In typical office buildings
20 – 40 % of occupants have SBS symptoms
20 - 40% find the IAQ unacceptable (even though existing ventilation standards are met)

Field studies show substantial rates of dissatisfaction in practice

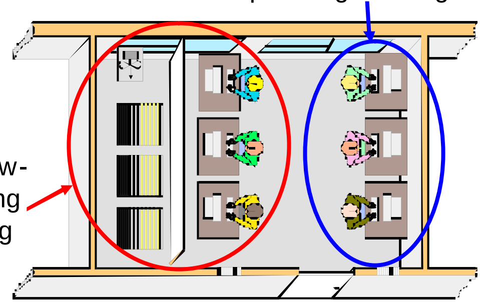
The benefits of improved indoor environment (IAQ)

IAQ impacts occupants' comfort, health and performance



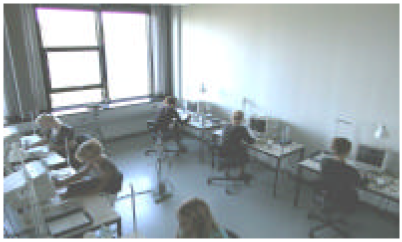
Experimental set-up at DTU

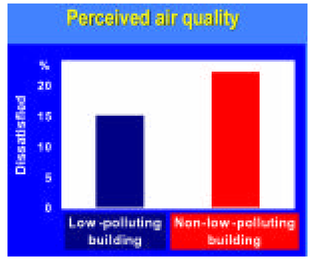
Low polluting building

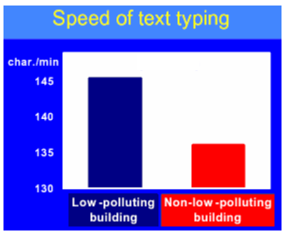


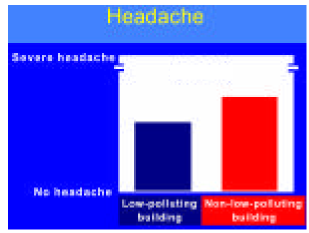
Non low-polluting building

The benefits of improved indoor environment (IAQ)





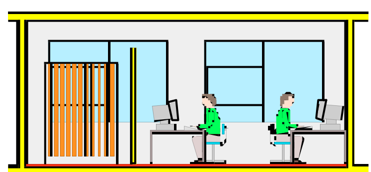




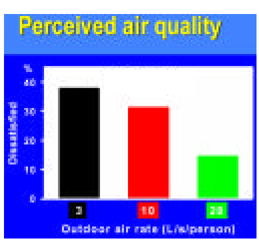
The benefits of improved indoor environment (IAQ)

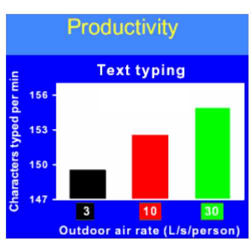
Experimental set-up at DTU

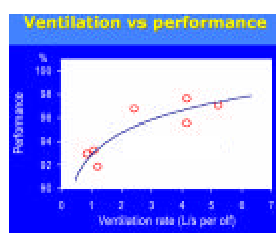
Outdoor air rates:



3 L/s/person (0.6 h^{-1})
10 L/s/person (2 h^{-1})
30 L/s/person (6.0 h^{-1})







The benefits of improved indoor environment (Thermal)

General thermal comfort

Personal factors
- Clothing
- Activity

Environmental factors
- Air temperature
- Radiant temperature
- Air velocity
- Humidity

Local thermal comfort

- Floor surface temperature
- Vertical air temperature difference
- Draught (mean air velocity, turbulence, air temperature)
- Radiant temperature asymmetry (heated/cooled ceiling, warm/cool wall)

10 % decrease in dissatisfied will increase performance by 1.5 %

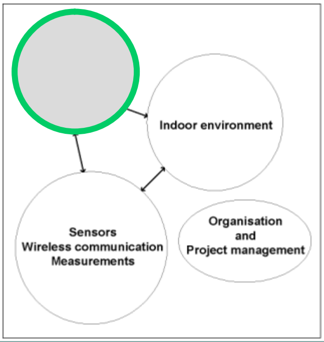
The benefits of improved indoor environment (IAQ)

Potential savings and productivity gains are enormous

Macroeconomic estimation of productivity gains of improved IEQ

Source of productivity gain	Potential annual health benefits	Potential US annual savings or productivity gain (1996 USD)
Reduced respiratory illness	16 – 37 mill avoided cases of common cold or influenza	**6 – 14 billion USD**
Reduced allergies and asthma	18% to 25% decrease in symptoms for 53 million allergy sufferers and 16 million asthmatics	**1 – 4 billion USD**
Reduced SBS symptoms	20% to 50% reduction in SBS symptoms experienced by 15 mill workers	**10 – 30 billion USD**
Improved worker performance from changes in thermal environment and lighting		**20 – 160 billion USD**
Total cost of energy in US commercial buildings		**70 billion USD**

(Fisk 2000)



THE LINK BETWEEN
IAQ
HVAC (Heating, Ventilation and A/C)
AND SENSORS

The link between IAQ, HVAC and sensors

Traditional building HVAC control strategies are often insufficient to provide a satisfactory indoor environment

Intelligent buildings with new, promising strategies are emerging ......

- Reliable, accurate and inexpensive sensors to measure key IAQ parameters are becoming available
- Processes such as **"Constant Commissioning",** an ongoing process to resolve operating problems, improve comfort, optimize energy use and identify retrofits

..... they need to be combined with methods of using these measurements in HVAC control strategies.

Legislation, i.e. the EU Energy Performance of Buildings Directive may help

- Integrated built-in sensors for diagnostics and inspection purposes
- Continuous calculation of energy consumption
- Explicitly specifies that reduction of energy consumption should not compromise occupants comfort, health and productivity.

Future needs for HVAC control strategies

- Improvements to existing sensors and some features of new sensors:
  - Low cost, small size sensors integrated into HVAC/IAQ system components
  - Self-calibrating, self-testing, self-diagnosing, and self-reporting sensors
  - Sensors that automatically detect the need for a measurement
  - Low power consumption
  - Built-in algorithms for diagnostics, service and inspection routines
  - Reliable. Low-drift,
  - Running calculation of energy consumption
  - Incorporation of low-cost processing and memory on sensor elements to generate information from raw data and to store that information, reporting data only when anomalies occur
  - Easy to implement (plug-and-play). Better system integration
  - Communication (including a wireless option to reduce installation costs)
  - Feedback to user regarding energy consumption and indoor environment status
  - Long life (> 10 years)
  - Documented system effects and pay-back

  - ....the list is long ……

All these aspects are related to sensors and measurements …………

Future needs for HVAC control strategies

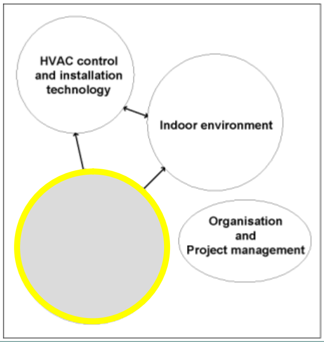
Technology drivers:

- Automotive industry
- Aerospace industry
- Military applications
- High end buildings
  - concert halls, conference rooms….




But comfort and prestige in buildings and homes could also be a driver

MORE ABOUT SENSORS FOR BETTER IAQ



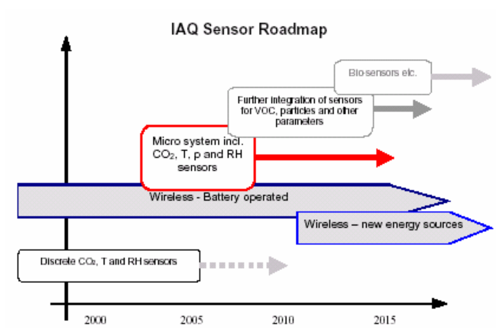
What do we want to measure – and how well?

Main IAQ parameters:

- Temperature
- Carbon dioxide concentration
- Relative humidity
- Pressure variations

Next step

- Particles (dust, pollen ...)
- Volatile organic compounds (VOC's)
- Other gases

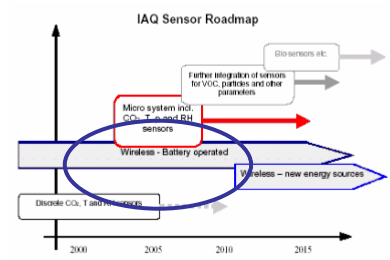


	CO_2 concentration (ppm)	Relative humidity (%)	Temperature (°C)	Pressure variations (Pa)
Operating range	0-3000	10-90	0-40	0-1000
Overall accuracy	+/- 50	+/- 5	+/- 0.5	+/- 100
Resolution	5	1	0.1	1
Cross sensitivity	<2-3%	<2-3%	<2-3%	<2-3%
Response time	60 sec	120 sec	60 sec	0.01-10 Hz

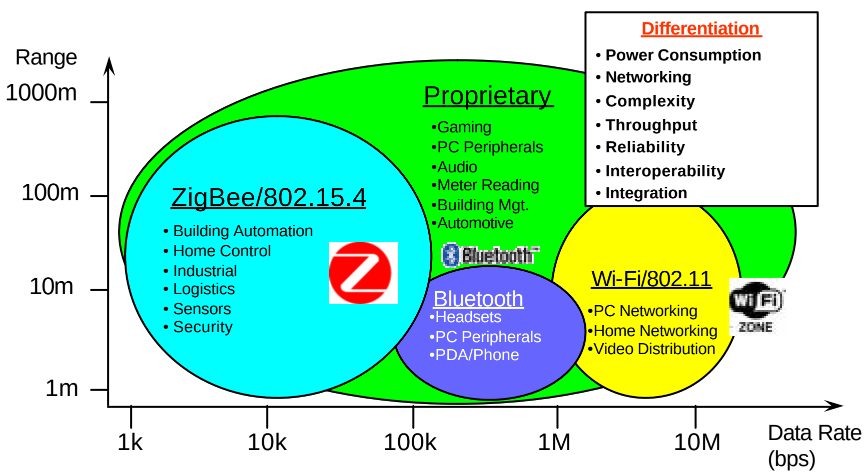
Tentative specifications of the multi-sensor in terms of measurement performance

Wireless monitoring and control systems

- Large number of nodes → wireless solutions are required
- Low-complexity and low power protocol
- Low system cost
- Sensor nodes have typically only limited amount of data to send
  - Very low raw data rate (few kBits/s)
  - Very small amount of data (couple of Bytes)
- Short to medium ranges (meters / tens of meters)
- Sensor nodes remain "quiet" in long periods of time
- Very long lifetime requirements
  - up to several years
  - unattended operation



A note about short range communications



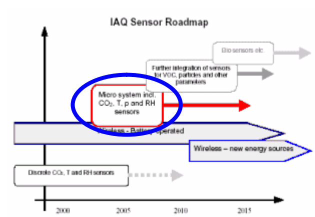
Wireless monitoring and control systems

ZigBee as a suitable candidate ?

Standard	ZigBee™ / IEEE 802.15.4	Wi-Fi™ / IEEE 802.11b	BlueTooth™ / IEEE 802.15.1
Application focus	Monitoring & Control	Web, Email, Video	Ad hoc cable Replacement
Stack Size (kBytes)	< 128	1000 +	250 +
Battery Life (days)	100 – 1000 +	0.5 - 5	1 - 7
Network Size (#nodes)	~Unlimited (65536)	Many	7
Bandwidth (kbps)	250	11 000	1000
Range (meters)	100 +	100	10 +
Target BOM costs	< $ 3	$ 9	$ 5

Examples of what sensor technologies are available

- **IR** technology offers highly sensitive, selective and reliable gas sensors
  - MEMS based IR sources, IR detectors, tunable optical filters, and complete gas and humidity sensors are available
  - IR gas sensors are still expensive due to large size, expensive components, packaging, and drift compensation. Higher level of integration is required
- A **DOE** (Diffractive Optical Element) based CO_2 sensor
- A MEMS based **photo-acoustic** gas sensor for CO_2
- **Electro-acoustic** MEMS-implemented CO_2 sensors



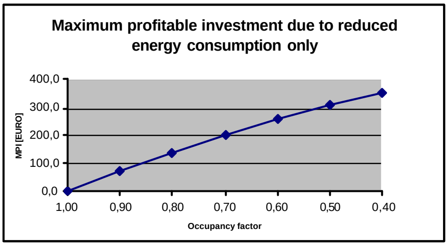
Why **MEMS** for multi-sensors?

- MEMS based sensors are by their small size and fabrication and packaging technology potentially suitable for multi-sensor integration
- Temperature sensors are easily implemented as an integral part of standard electronics
- Multi sensors are often based on integration of several sensors at the same electronic boards
- MEMS devices are potentially easy to integrate since the are small and often based on the same principles (piezoresistive, capacitive and optical)
- MEMS also opens for a higher degree of monolithic integration
  - Temperature sensors as part of the gas sensor chip

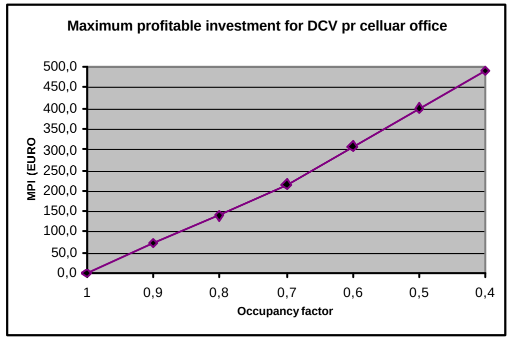
Is ”demand controlled ventilation” the solution

Possible to calculate the maximum profitable investment:

- **Due to reduced energy use only**
- **Due to reduced energy use, installation cost and reduction of technical area**



Energy use, installation cost and reduction of technical area



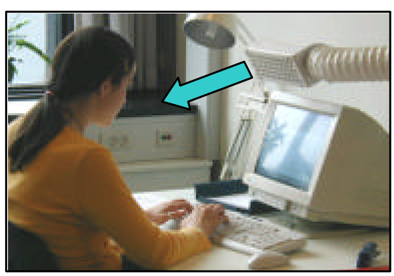
The impact increases with increased electrical energy cost

- Electrical energy cost of 0.25 EURO/kWh
- MPI is 700 EURO per celluar office

Is ”Personalised ventilation” the solution

Large differences between occupants in regard to:

- **Preferred Temperature**
- **Air movement sensation**
- **Clothing insulation level**
- **Activity level**
- **Air quality perception**



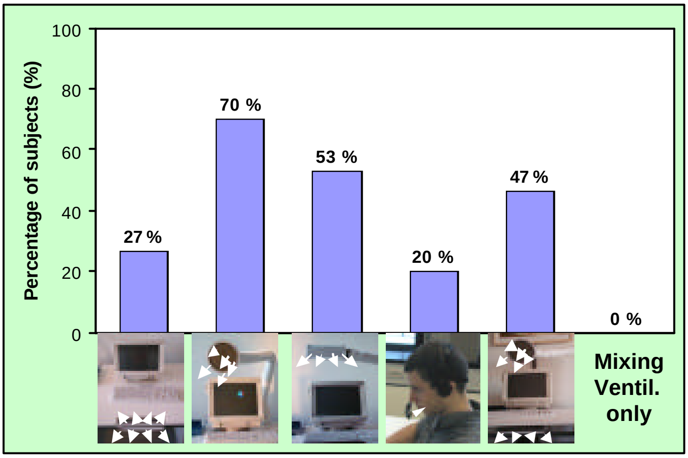
Personalized ventilation

Clean air is supplied to the breathing zone
Individual control & preferred environment:

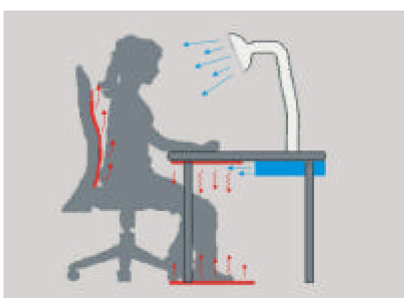
- **airflow direction**
- **preferred temperature**
- **preferred velocity: 0.2 m/s – 1.8 m/s**

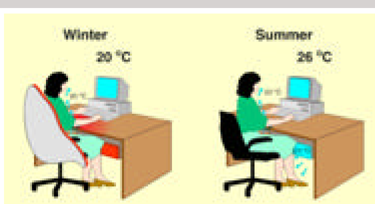
Is ”Personalised ventilation” the solution

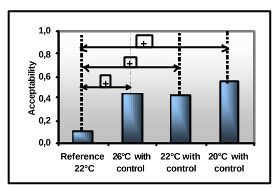
Which system(s) would you like to have on your desk?



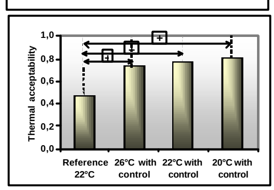
Next step ”Personalised heating and ventilation”



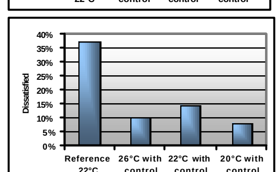




Perceived Air Quality

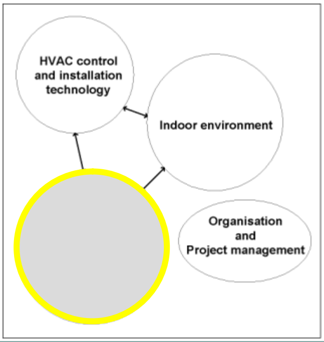


Thermal Comfort



General satisfaction

EXAMPLES OF IAQ SENSORS THAT HAVE BEEN IDENTIFIED DURING THE PROJECT



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Example – IAQ sensors in the Nordic area

Hök Instrument Q-AIR wall-mountable sensor for measuring CO_2, temp, RH

SenseAir infrared CO_2 sensor for embedded solutions

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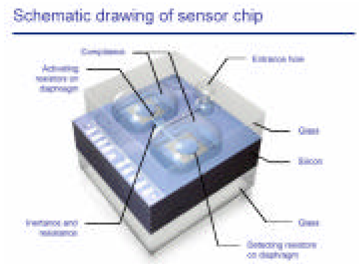
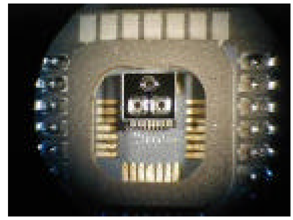
Västerås, Sweden 9 May 2006

Other examples of IAQ sensors

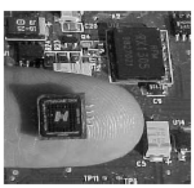




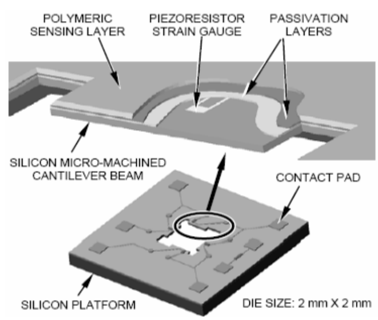
Sensor chip area: 3 x 3 mm. Packaged in a standard ceramic package

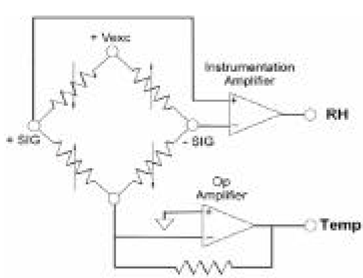
MASCOT - Micro-Acoustic Sensors for CO2 Tracking.
The MASCOT project was co-financed by the EU IST programme

Other examples – MEMS multisensor from the aerospace and industry sector



HYGROMETRIX
The Hygrotron
http://www.hygrometrix.net

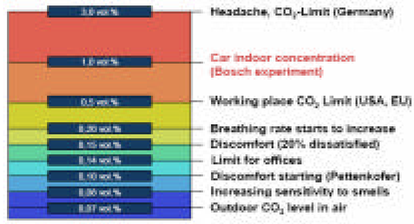




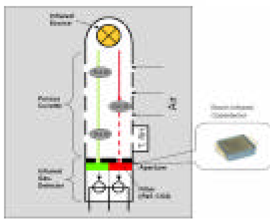
Applications
- Environmental monitoring and control
- Avionics and aerospace
- Dehumidification, industrial drying
- HVAC
- Precision instrumentation

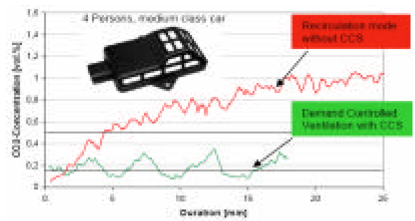
Other examples – from the automotive sector

Source: Bosch Medical Service



The Climate Control Sensor by Bosch
(http://rb-k.bosch.de)





Other examples – from the automotive sector

Introduced att the Las Vegas Automobile Accessory Fair, Nov.1-4, 2005

CO_2Engine
-LO

AA-950 BLACK

Other examples of IAQ sensors – in consumer products

Plug-in CO2 sensor modules

Korea is catching up…

Clock radio +
demand controlled ventilation
from Korea…

Clean Air Tec Fair,
Korea Oct.5-7, 2005

Future needs for HVAC control strategies

Barriers:

- Conservatism about technical installations in buildings – HVAC components and installations traditionally have a long lifetime
- A lack of understanding of how complex building automation systems interact with their environment
- Degree of adoption and implementation is slow
- Often limited to flagship buildings. Demonstration projects are important but specific business cases are better
- Unclear commercial potential and costs. Is it possible to provide convincing evidence to investors and end users ?
  - (Can investments be justified? How do we calculate/document payback time?)
- Can you provide value for money to the end users?

“Better” sensors and solutions are necessary

There is a worldwide interest and future market for IAQ multisensors

Some challenges

• Low cost – will enable several sensors even in one room, reducing difficulties in the selection of sensor location

• Low power will fulfill battery demands – or alternatives to batteries

• On-chip diagnostics of system function and performance is important

• Measurement aspects: Cross sensitivity (influences from temperature, humidity, dust), poisoning, long term drift

The MONTIE initiative in 2006 will focus on trends and drivers for innovative HVAC installations and control techniques

Thanks to the following for most of the information in these slides

Indoor environment
Bjarne Olesen, Jørn Toftum, Arsen Melikov, DTU/ICIEE

Sensors
Hans Martin, SenseAir
Per Gløersen, SensoNor
Bertil Hök, Hök Instrument
Peter Østbø, Ralph Bernstein, SINTEF
Jan Nielsen, DTI

HVAC systems, wireless communication etc.
Johnny Holst, NTNU
Jens Møller Jensen, Peter Gravesen, Danfoss
Mads Mysen, SINTEF Bygforsk
Per Anker Jensen, DTU/BYG

Thank you for your attention!

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