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**SDU - Center for Energy Informatics** is an interdisciplinary research, development and innovation center that brings together software engineers, computer scientists, applied physicists, control engineers and social scientists in the application of information technology to facilitate the transition towards a sustainable energy system by intelligent integration and optimization of the energy flexibility found in buildings and industrial processes with the fluctuating energy supply from renewable sources, like wind and solar.


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# LEOB

## Living Lab for Energy Informatics and Occupant Behavior


Mikkel Baun Kjærgaard
Associate Professor
SDU Center for Energy Informatics

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# Why a Living Lab?

- Buildings are responsible for around 40% of total energy usage
- Occupant behavior has a large impact on energy usage in buildings

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# Why a Living Lab?

- New software solutions have the potential to change how we experience, operate and control buildings.

Example from US collaboration network

https://gocomfy.com

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# Establish Living Lab

Create a Living Lab for Energy Informatics and Occupant Behavior in the OU44

1. Living Lab facilities enable monitoring of occupant behavior and data sharing.
2. Establish small pilots that use the facilities in student and research projects

Supported by

EnergiFyn SDU

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# Data Sharing within SDU

- Website on SDU internal network
  - How to guides
- Data Sharing Platform and API
  - sMAP platform through collaboration with UC Berkeley
  - Data without Privacy Concerns

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# Ongoing Student Pilots

**Peter & Halldór**
Software Engineering

**Daniel & Alexander**
Energy Technology

**Jens & Dan**
Software Engineering

**Almir & Thomas**
Software Engineering

*4 More student pilots are ongoing*

# Ongoing Research Pilots

- Ongoing Research Projects
  - COORDICY: IKT-drevet koordinering til opnåelse af Energieffektiviseringsmålene for 2020 i offentlige og private bygninger
  - DRComCap: Håndtering af demand-response kapaciteten fra erhvervsbygninger
  - More to come…

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# COORDICY: IKT-drevet koordinering til opnåelse af Energieffektiviseringsmålene for 2020 i offentlige og private bygninger

Christian Veje

Associate Professor

SDU Center for Energy Informatics

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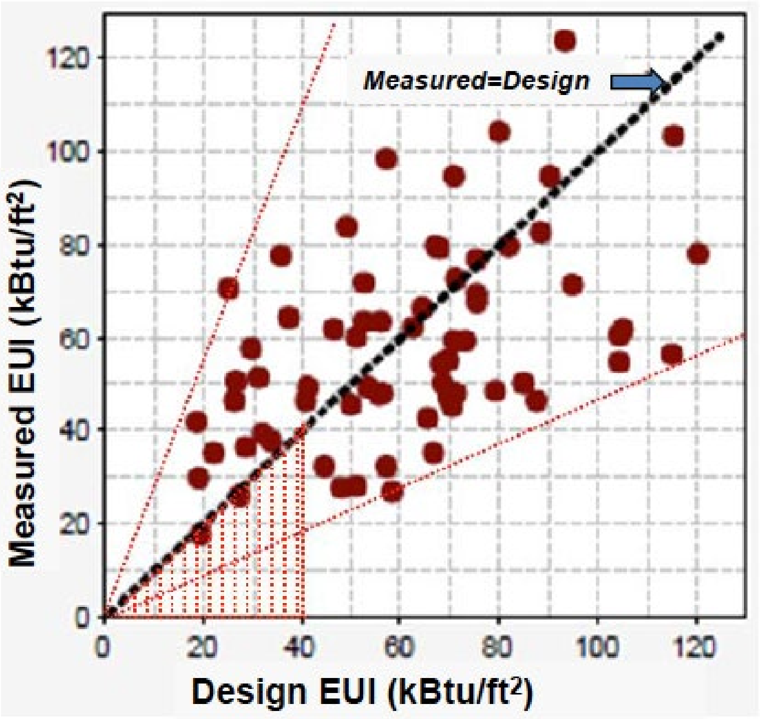
# **COORDICY** ICT-driven Coordination for Reaching 2020 Energy Efficiency Goals in Public and Commercial Buildings

- National
  - SDU Center for Energy Informatics
  - Danish Technological Institute
  - Danish Building & Property Agency
  - Municipality of Aarhus
  - Municipality of Odense
  - Odense University Hospital
  - Green Tech Center
  - Rambøll
  - Siemens
  - INSERO Software
  - ReMoni
  - Develco Products

- International
  - UC Berkeley, i4Energy
  - Lawrence Berkeley National Laboratory
  - NASA Ames Sustainability Base
  - Danish Cleantech Hub in NY

# Background

- Buildings account for 40% of the world's energy consumption
- Existing buildings are far behind modern energy efficiency standards
- New buildings often fail to meet the goals of their energy efficiency standards




Source: Energy performance of LEED-NC buildings, NBI, 2008

# Project Goal

*Provide scientifically based, practically implementable and economically viable **ICT-centered solutions** to **close the energy-performance gap** in newly built energy-efficient **public and commercial buildings** and **improve the energy-performance of existing buildings**.*

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# COORDICY - Objectives

**ICT solutions for**

- Benchmarking of existing buildings
- Diagnostics to identify causes for gaps
- Advancing the intelligence of building control systems
- Assessing tradeoffs between different energy-retrofit technologies and levels of building control

**Modeling and Simulation**

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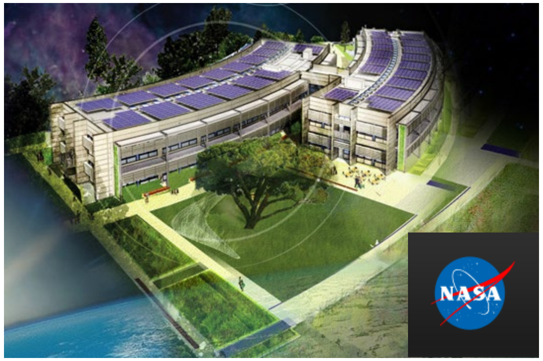
# COORDICY case study buildings


UC Berkeley - Sutardja Dai Hall
13,099 M2 (141,000 $ft^2$)

OUH Svendborg
65,000 $m^2$ (699,654 $ft^2$)

Green Tech Center – BR2015
3,500 $m^2$ (37,674 $ft^2$)




NASA Sustainability Base - LEED Platinum
4,645 $m^2$ (50,000 $ft^2$)

AARHUS
KOMMUNE

ODENSE KOMMUNE

2.900.000 $m^2$ (31,215,340 $ft^2$)

OU 44 – BR2015
8,000 $m^2$ (86,111 $ft^2$)

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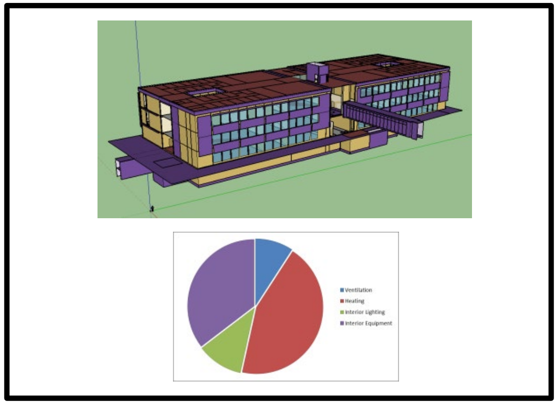
# Building modeling approaches

**Whole-building model**

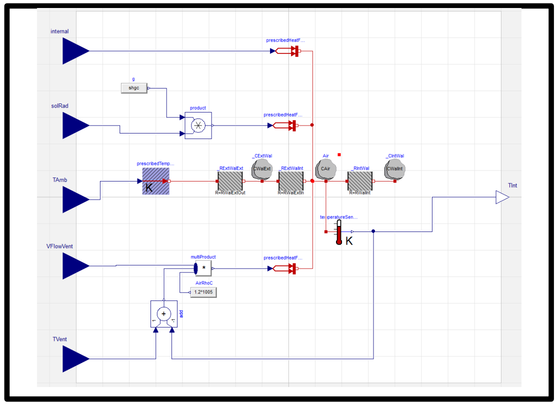


Aims:

- overall yearly energy consumption
- near-future overall energy consumption prediction (online simulations)
- fault detection and diagnostics

Tool: EnergyPlus

**Zone models**



Aims:

- short-term indoor environment quality prediction
- model predictive control on a zone level
- fault detection and diagnostics

Tool: Modelica

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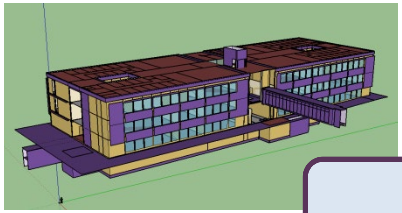
# Whole-building model

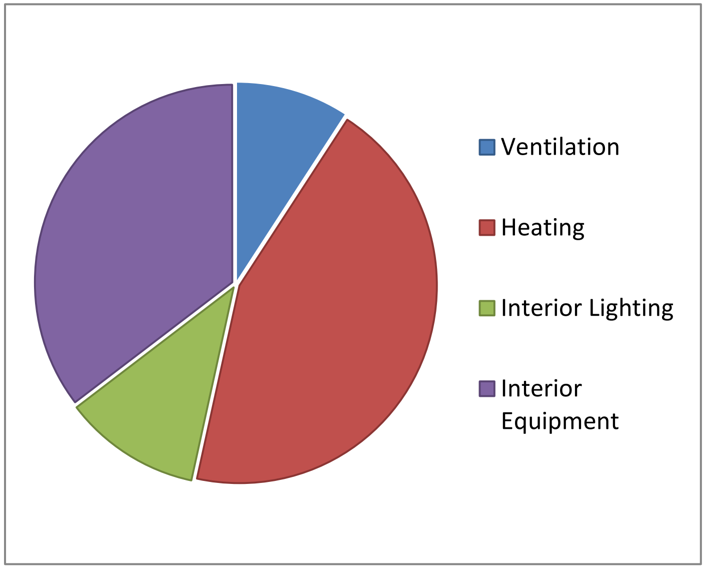


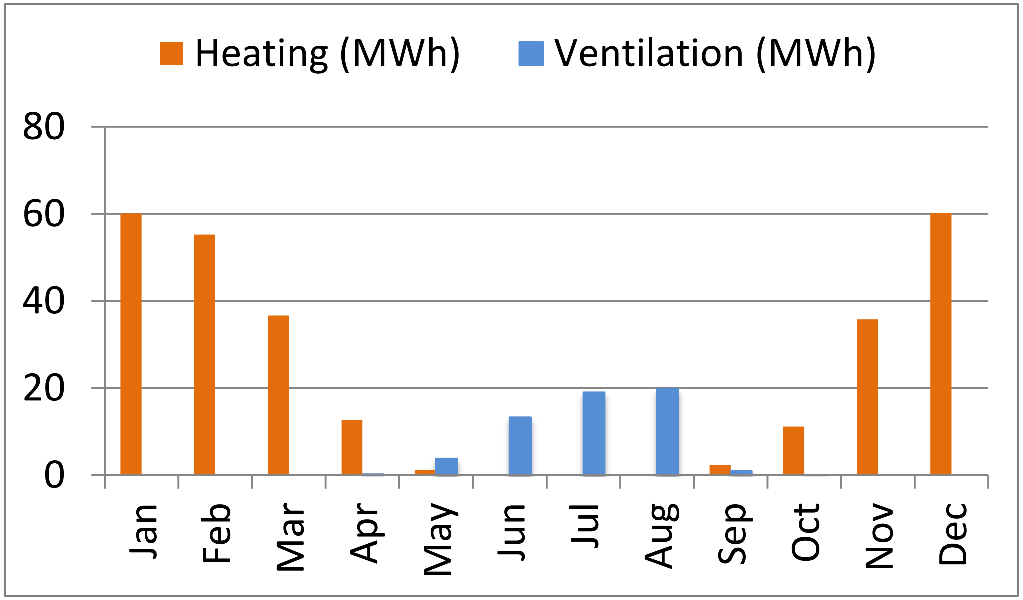
Google SketchUp

EnergyPlus

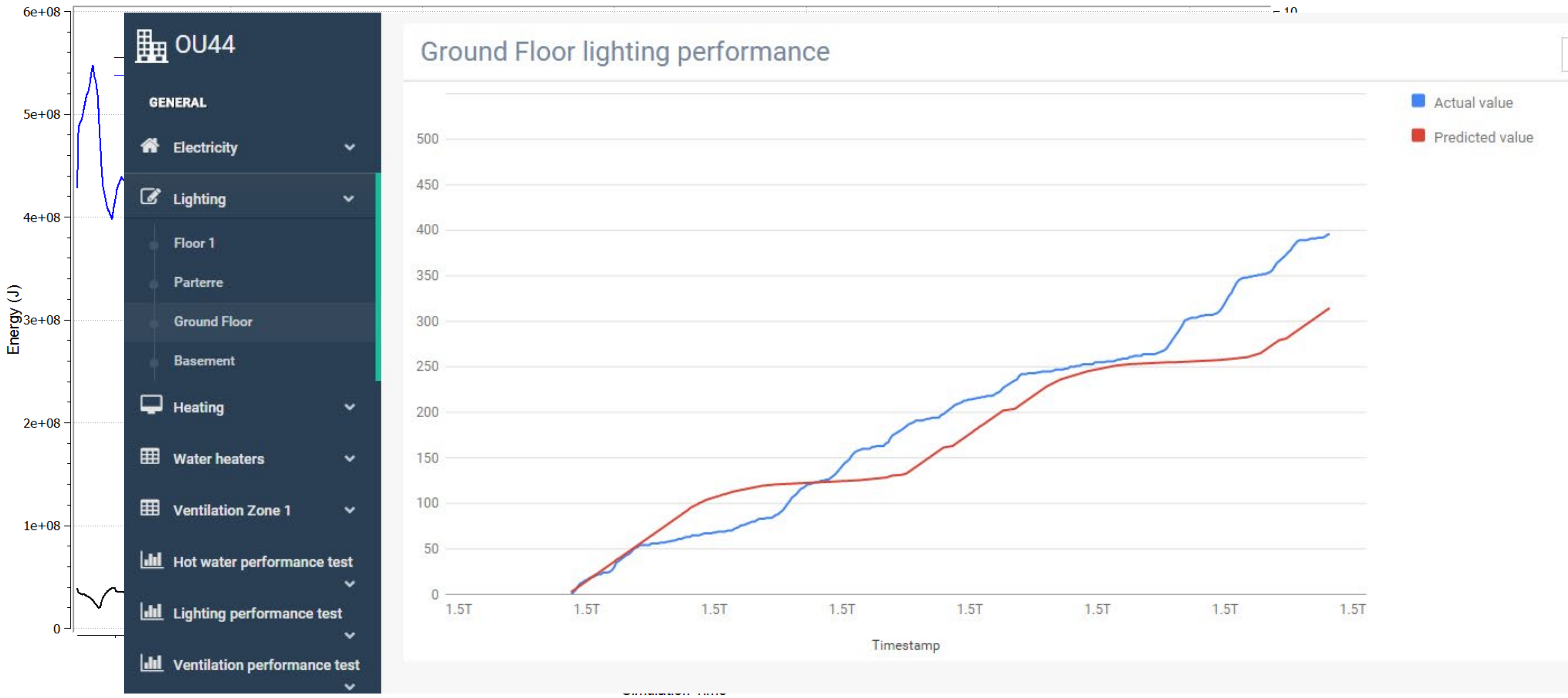
Revit

OpenStudio



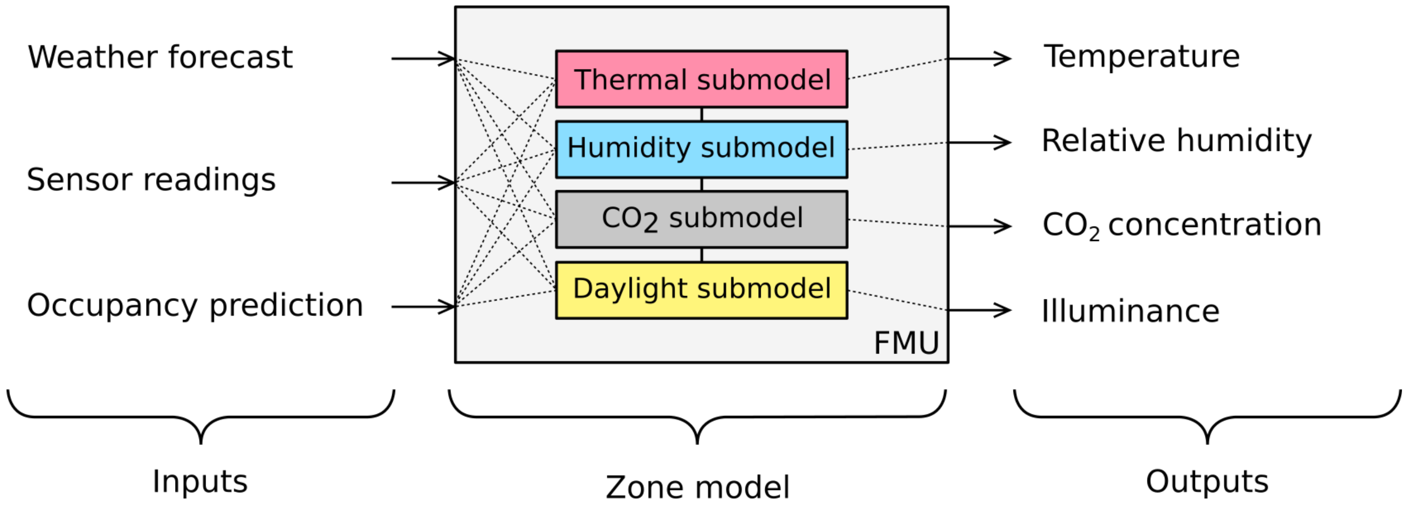
# Whole-building model




*Requirement for accuracy :*

***Validated model based on measurements***

# Zone models




- **Provide predictions of the indoor environment parameters on the level of individual rooms**
- **Enables energy and comfort optimization**
- **Enables detailed fault detection and diagnostics**

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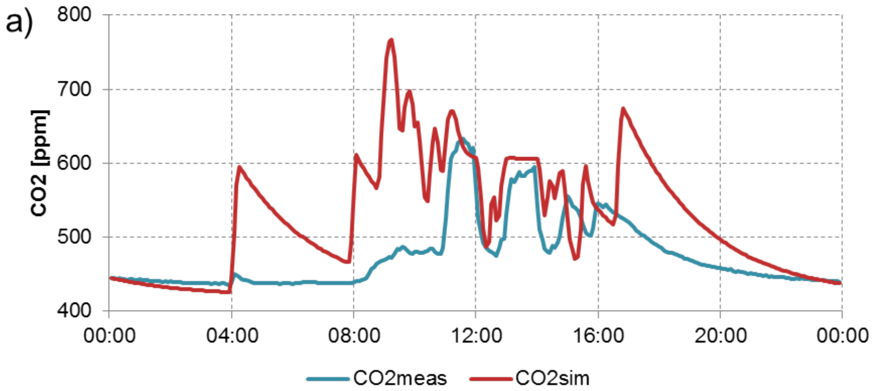
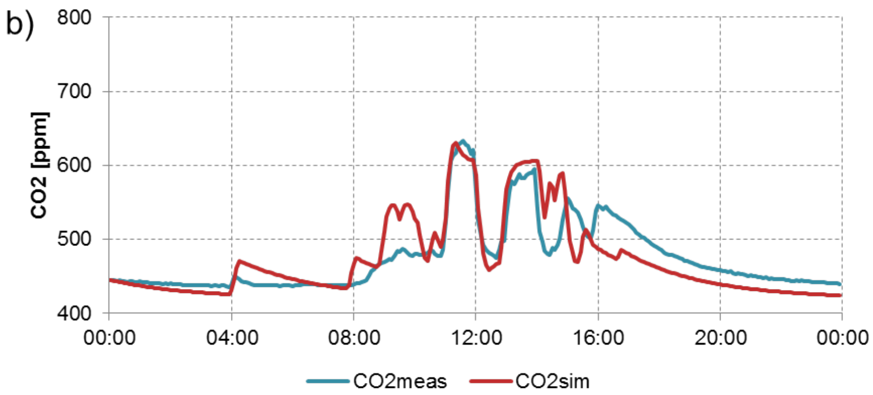
# Zone modeling

## Single room CO2 simulation and measurement




**Assumed maximum occupancy**



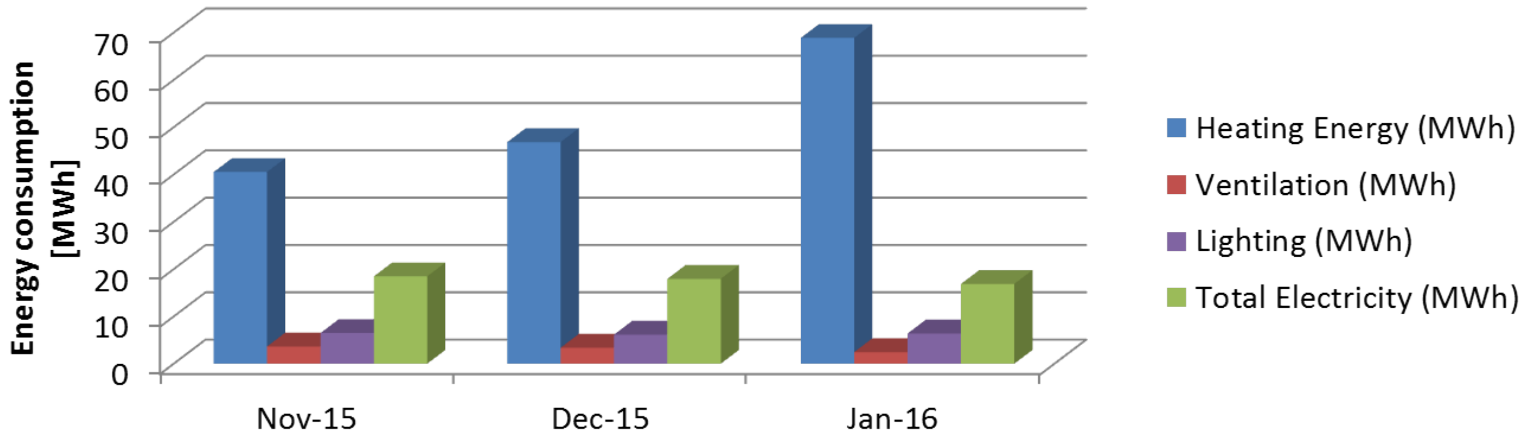

**Improved occupancy model**

*Requirement for accuracy in prediction:*

***Validated models based on measurements***

# Sensors and meters

1) Energy consumption meters on each floor



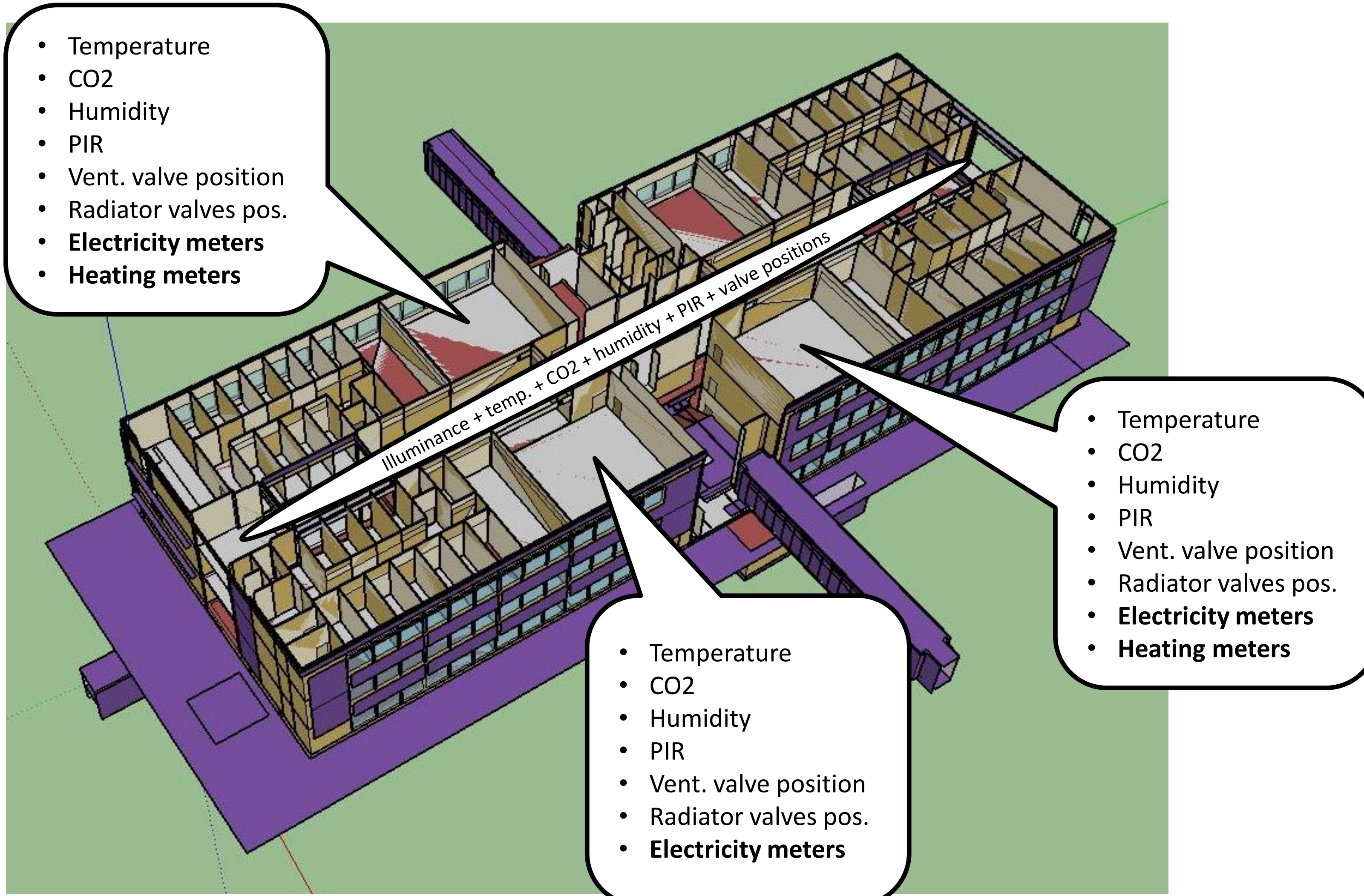

2) Standard sensor equipment in all rooms:

- temperature
- CO2
- relative humidity
- PIR
- radiator valve positions
- ventilation valve positions

3) Standard sensor equipment in halls:

- temperature
- CO2
- relative humidity
- PIR
- radiator valve positions
- ventilation valve positions
- illuminance

# Additional sensors: second floor



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DEMAND-RESPONSE
Capacity Management in Commercial Buildings

# DRComCap: Håndtering af demand-response kapaciteten fra erhvervsbygninger

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# Challenges for the DK Electricity Grid

- Danish Goals:
  - Integration of renewables (Wind, Solar, …)
  - Increased electrification of heating (small and large heat pumps) and transportation result in peak load problems.
  - Decrease maintenance cost by avoiding upgrades of lines and transformers.

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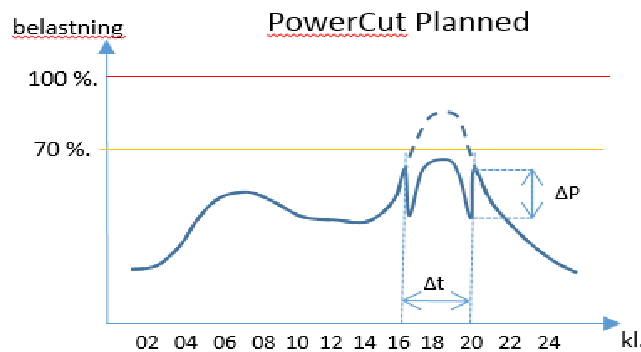
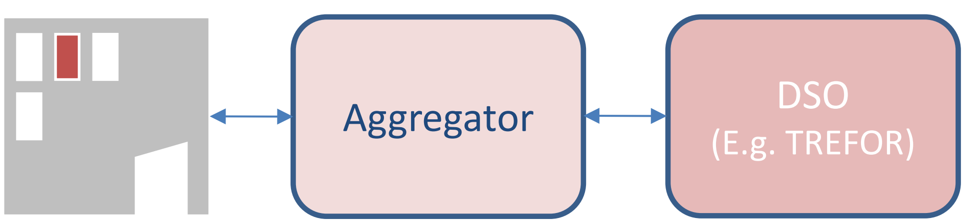
# Demand Response for what?

- Reduce peak loads in the distribution grid
  - DR-ydelse PowerCut




iPower

  - Contract between Aggregator and building owners (n)



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# Why Commercial Buildings?

- Commercial Buildings for DR
  - Relevant share of consumption
  - Predictable loads
  - Centralized control

*LBNL US Results are promising. However, less H and AC loads in DK*

| Site | HVAC | | | | | | | | | | | | | Lighting | | | | | Other | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Global temp. adjustment | Duct static pres. decrease | SAT decrease | Fan VFD limit | RTU Shut off | Duty Cycling RTUs | Pre-heating | Pre-cooling | Fan-coil unit off | Cycle electric heaters | Cycle AHU Fans | Cycle VAVs | Set up CO2 Setpoints | Common area light dim | Office area light dim | Turn off light | Dimmable ballast | Bi-level switching | Non-critical process shed | Elevator cycling | Slow Recovery |
| McKinstry | S | | | | | W | | S | | | | | | | | S | | | | | W |
| Target - T1284 | WS | | | | WS | | | | | | | | | | | | | WS | | | |
| Seattle Municiple Tower | WS | | | | | | | | | | W | W | | | | | | | | | WS |
| Seattle University | WS | | | | | W | W | S | | W | W | W | W | | | | | | | | W |

| Site | Test | Test 1 | Test 2 | Test 3 | Test 4 | Average |
|---|---|---|---|---|---|---|
| McKinstry | W/m2 | 2.3 | 1.5 | 1.4 | 2.5 | **1.9** |
| | kW | 25 | 16 | 15 | 27 | **21** |
| | WBP% | 9% | 6% | 5% | 10% | **8%** |
| Target - T1284* | W/m2 | 4.7 | | 4.7 | | **4.7** |
| | kW | 102 | | 104 | | **103** |
| | WBP% | 19% | | 19% | | **19%** |
| Seattle Municipal Tower | W/m2 | 5.3 | 5.6 | 1.7 | 3.72 | **4.1** |
| | kW | 678 | 717 | 220 | 477 | **523** |
| | WBP% | 15% | 15% | 4% | 9% | **11%** |
| Seattle University | W/m2 | 13.1 | 9.5 | 11.8 | 10.4 | **3.3** |
| | kW | 141 | 102 | 127 | 112 | **121** |
| | WBP% | 20% | 15% | 19% | 17% | **18%** |
| All Sites | W/m2 | | | | **Average*** | **3.5** |
| | kW | | | | **Total*** | **767** |
| | WBP% | | | | **Average*** | **14%** |

Sheds are calculated using OATR model with no adjustments
* Total value is the sum of the averages for each site
** Average Value is the average of each site's average

*Piette, Mary Ann, Sila Kiliccote, and Girish Ghatikar. "Field Experience with and Potential for Multi-time Scale Grid Transactions from Responsive Commercial Buildings ." In ACEEE Summer Study on Energy Efficency in Buildings, Pacific Grove, CA, 2014.*

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# What About the Building Occupants?

- Studies often do not consider the impact on occupant comfort.
- Building and work regulations.

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# Project Vision

The project demonstrates how smart grid technology enables operators of commercial buildings to provide flexibility services to existing flexibility markets and to DSOs.

- Participants
  - Insero A/S – Project leader / software development / energy sociology
  - SDU – Research and development, and Trial site
  - GreenTech Center – Trial site
  - Tre-For A/S – DSO
- Supported by EUDP

# Project Goals

- Implement an **ICT system** that provides demand-response services via the **OpenADR protocol** and **multi-objective control**.
- **Demonstrate** the ability in two commercial buildings to deliver demand-response capacity without compromising the **tenants' comfort** and with a predictable response:
  – Green Tech Center (ventilation)
  – Mærsk McKinney Møller Institute at the University of Southern Denmark (ligthing)
- Use powergrid data to **evaluate the benefits** that the demonstrated demand response services provide to a DSO at scale.