POSITIVE-ENERGY BUILDINGS THRU BETTER CONTROL DECISIONS PEBBLE

FP7-ICT-2009.6.3: ICT for Energy Efficiency
B. ICT support to Energy-Positive Buildings and Neighborhood
http://www.pebble-fp7.eu

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4th Monitoring and Control Concertation Meeting
M&C Cluster on Smart Buildings

PEBBLE
Project Information

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	PEBBLE Participants
1	Technical University of Crete (GR)
2	Fraunhofer Institute for Building Physics (DE)
3	RWTH Aachen University (DE)
4	Graz University of Technology (AU)
5	ARMINES (FR)
6	CSEM (CH)
7	Saia-Burgess Controls (CH)

Project Acronym: PEBBLE

Project Number: 248537

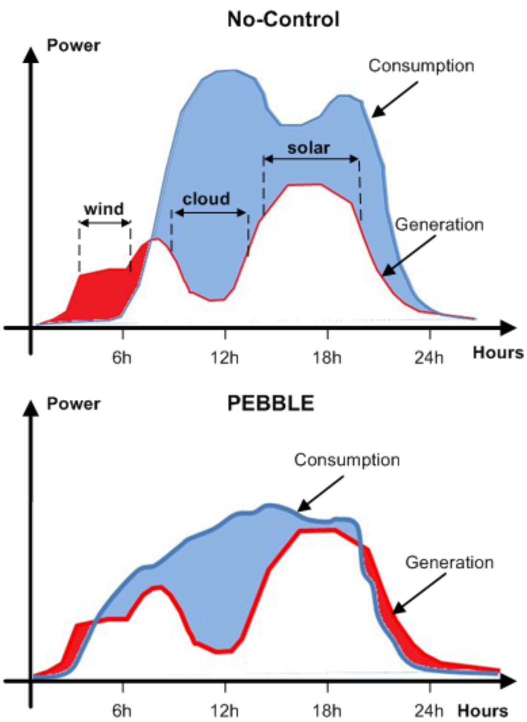
Project Start Date: January 2010

Duration: 3 Years

Funded by: EU FP7

Program Name:
ICT for Energy Efficiency,
FP7-ICT-2009.6.3

Key Issues Toward Energy-Positive Buildings (EPBs)



Area under consumption curve: energy required for building operation.
Area under generation curve: energy available by installed renewable energy sources.
Red Area: Surplus energy available.
Blue Area: Energy purchased from the grid.

Current View: "Static"

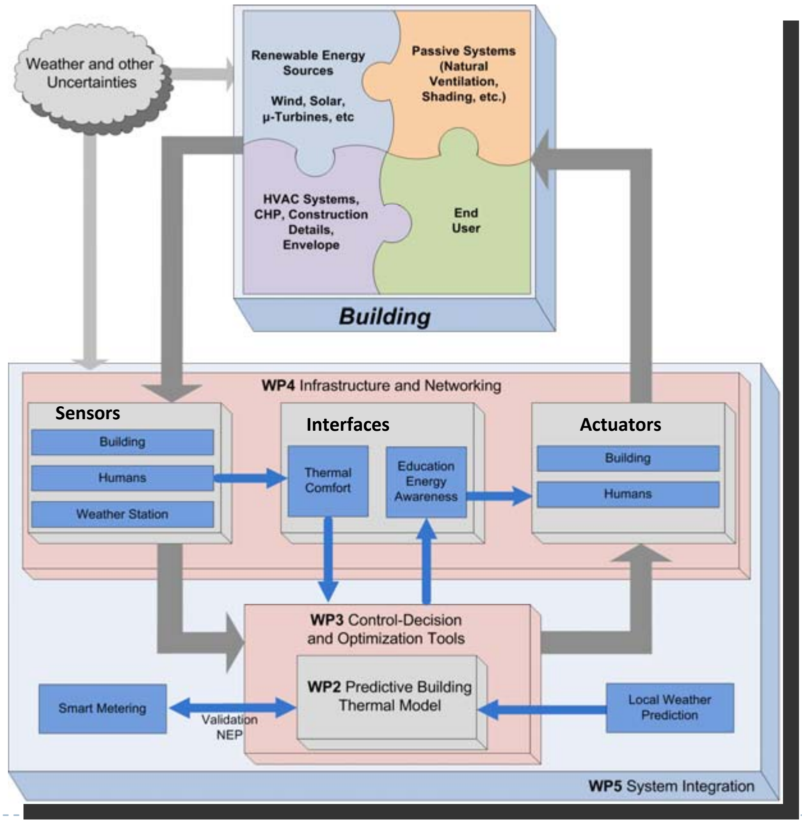
PEBBLE View: "Dynamic"
Select a relevant performance metric, the Net Expected Benefit (NEB) (e.g. the net energy produced over a certain period).

Maximize NEB by:
intelligently shaping demand to perform generation-consumption matching
subject to constraints (end-user thermal comfort, atypical availability of energy, reduced capacity demand at a certain time).

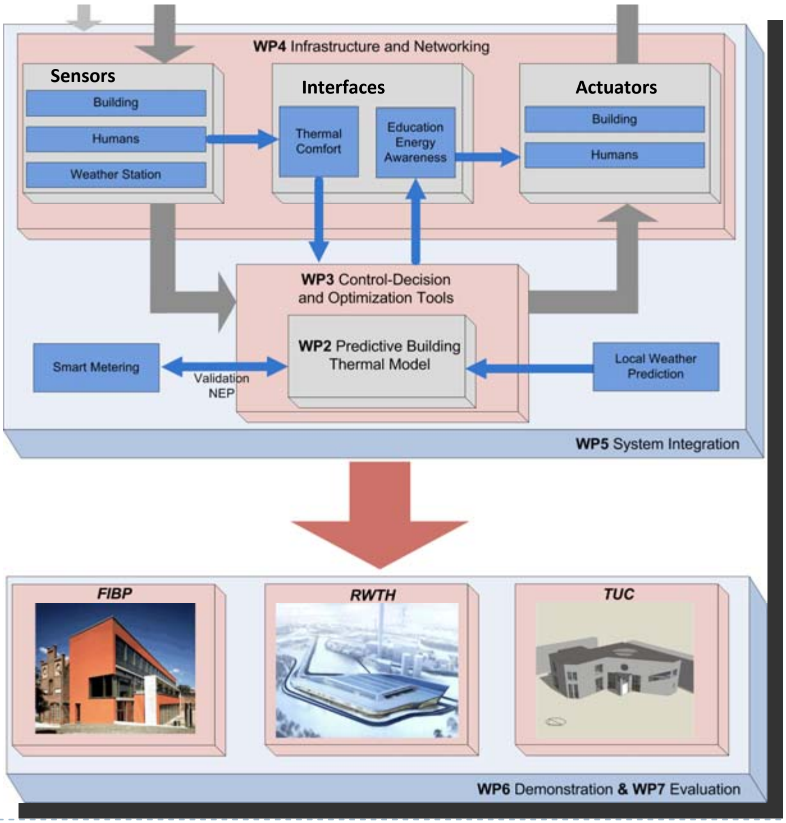
Which Requires:

- Decisions in (almost) real-time:
  - to operate building subsystems and
  - to account for:
    - unpredictable user-behavior,
    - occupancy scheduling and occupants' activity,
    - changing weather conditions, and
    - signals from the grid.
- These decisions have direct consequences to:
  - occupant thermal comfort,
  - energy efficiency, and ultimately
  - to the Net Expected Benefit (NEB).
- The complex interplay between the many parameters precludes empiricism or rule-based decisions and necessitates the development of generic decision tools.

PEBBLE Project: Conceptual Schematic…



PEBBLE Project: …Conceptual Schematic

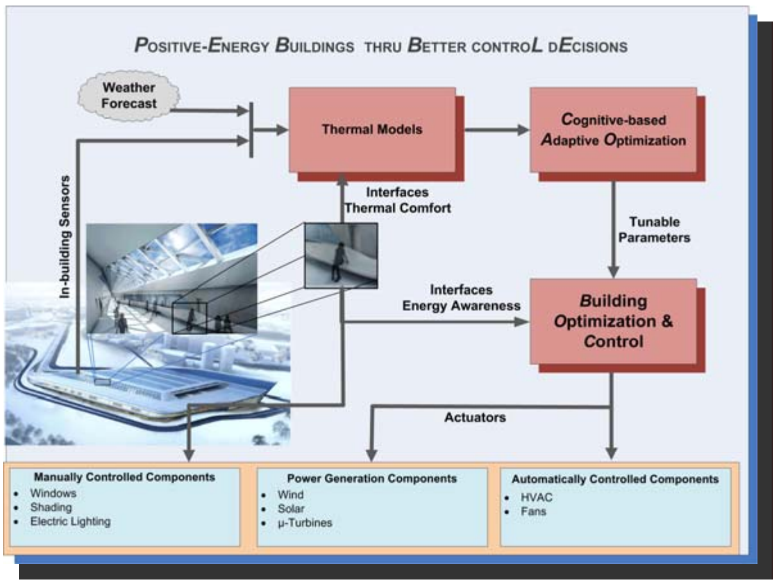


Elements of the PEBBLE System

1. Thermal models for the building that:
   - at the simulation level, are accurate and efficient representations of the building;
   - incorporate all passive and active building subsystems, as well as all energy-generation elements;

   and, given local weather data and/or weather prediction models:
   - can be used to predict thermal response, energy requirements, and estimate thermal comfort.
2. Efficient and robust Building Optimization and Control tools, that:
   - use sensor inputs and thermal models to evaluate potential scenarios;
   - take in (almost) real-time, decisions for the operation of the building subsystems;
   - operate with the goal of *maximization of the NEB* while retaining building conditions at user-acceptable comfort levels.
3. Sensors, actuators and interfaces to facilitate information interchange between the physical and the simulation layers.

The PEBBLE approach to Building Optimization and Control



Combine scalable Model-Predictive Control (MPC) approaches with Cognitive-based Adaptive Optimization (CAO) that provide fully-automated, safe and efficient fine-tuning and optimization of BO&C operations.

PEBBLE Demonstration Buildings
I. FIBP, ZENTRUM FÜR UMWELTBEWUSSTES

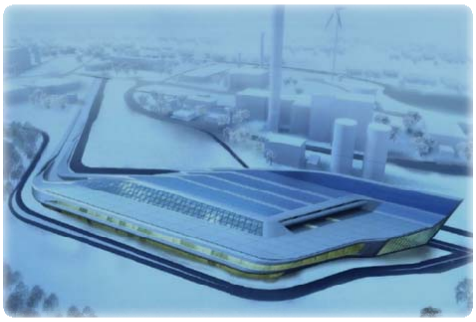
Location:
Kassel, Germany.

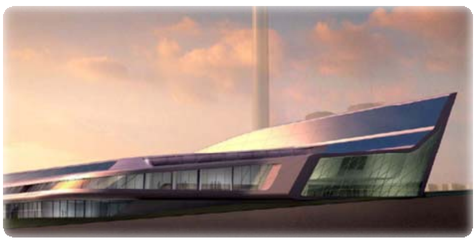
Characteristics:
Low-energy building.
Annual energy consumption ~ 32KWh/m^2

Energy systems:
Natural night-time ventilation.
Space cooling using geothermal soil collector.
Grid-connected to renewable energy sources.
Significant thermal mass.

Hypothesis Tested in PEBBLE:
Installation of Renewable-Energy Sources along with PEBBLE, will move the building from the low-energy to the energy-positive domain.

PEBBLE Demonstration Buildings
II. RWTH, E.ON ENERGY RESEARCH CENTER





Location:
Aachen, Germany.

Characteristics:
Interesting architecturally but challenging from an energy viewpoint due to unfavorable surface to volume ratio and large window sizes.

Energy systems:
Gas powered cogeneration unit.
Heat Pump Technology.
Photovoltaic Array.
Wind Turbine.
Heat recovery from server rooms.

Hypothesis Tested in PEBBLE:
In such non-traditional buildings good performance is achieved with a combination of energy-technologies *and* advanced control strategies.

PEBBLE Demonstration Buildings
III. TUC, MAINTENANCE SUPPORT BUILDING

Location:
Chania, Greece.

Characteristics:
Low-performance building.
Annual energy consumption~130 KWh/m^2
Thermal comfort problems for occupants.
Typical of existing buildings in Greece and elsewhere in Europe.

Energy systems:
Photovoltaic Array.
Wind Turbine.
Automatically-operated roof window.
Automatically-operated shading devices.

Hypothesis Tested in PEBBLE:
Good decisions by the PEBBLE tool can have a significant effect on energy efficiency. For existing buildings, the PEBBLE tool can be a cost-efficient solution to: achieve energy efficiency, reduce carbon footprint, lower operational costs. The PEEBLE simulation can be used to select energy efficiency measures for the buildings (e.g. roof insulation, fixed shading systems, building-related measures to allow night ventilation).

PEBBLE
Demonstration Objectives:

1. Energy-Positive for Demonstration Building I and *at least* Category A for Demo Buildings II and III.
2. >80% Theoretically Optimal Consumption-Generation Performance: a new indicator, the Generation-Consumption Effectiveness Index (GCEI) is introduced.
3. Acceptable thermal comfort (measured both by means of sensor data and user input).
4. PEBBLE Payback period <5 years.

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SEVENTH FRAMEWORK PROGRAMME

PEBBLE System:
I. Thermal Modeling

State of the art

Efficient, validated and reliable:
1. modeling and simulation tools for building components and subsystems;
2. weather prediction and forecasting models.

But:
1. The influence of user-behavior to the building performance is hard to ascertain.
2. Current simulation tools do not incorporate in the *thermal simulation of the building:* state awareness (via sensor measurements) and the effect of human and control actions.

Progress beyond the state of the art

"Just enough" accuracy: Model-order reduction for efficient *and* accurate predictions of performance and thermal comfort.

Use of measured data: Development of tools that take into account *sensor measurements* as well as human and control actions in making long-term predictions of the thermal behavior of the building.

Model-based Predictive Control: Adaptation, integration and refinement of the thermal models with the decision and control algorithms.

PEBBLE System:
II. Building Optimization and Control

State of the art

A rich variety of BO&C systems exist for real-time energy management and control. However the majority of these systems:
1.Base their reaction on current or short-term future conditions and, thus, are not applicable to BO&C for EPBs;
2.Are applicable only to *single-mode* BO&C (e.g. HVAC control without taking into account the effect of other control elements such as ventilation);
3.and, usually, are heuristic and/or data-driven.
A tedious and continuous *fine-tuning* is required for calibrating the BO&C system parameters.

Progress beyond the state of the art

Proactive BO&C systems are required to:
1.perform *multi-mode* optimization and control of all energy-influencing elements;
2.optimally schedule *long-term* EPB operation, and
3.interact and communicate with the end-users to guarantee *thermal comfort, user satisfaction and safety.*
Fully-automated, efficient BO&C system fine-tuning approaches are needed to guarantee rapid response and optimization of system operations.

PEBBLE System:
III. Sensors, Actuators and User Interfaces

State of the art

Existing technologies require considerable effort for installation and integration within the building.

Moreover, serious expandability, scalability and interoperability problems arise in the deployment of most existing technologies.

Progress beyond the state of the art

Scalable, expandable and interoperable systems are required for cost-efficient operation and deployment of the PEBBLE system in new and existing buildings.

Development of novel, low-power, wireless-based systems that employ mesh networking and can be applicable to buildings of arbitrary scale and complexity.

Integration of wireless sensing into the building monitoring & control chain.

PEBBLE Project: Abstract…

Abstract…

In the design and operation of positive-energy buildings a pragmatic target is maximization of the actual net energy produced (NEP) by intelligently shaping demand to perform generation-consumption matching. To achieve this, informed decisions in (almost) real-time are required to operate building subsystems and to account for unpredictable user-behavior, occupancy scheduling and occupants' activity and changing weather conditions. These decisions have direct consequences to occupant thermal comfort, energy efficiency and, ultimately, to the NEP. The complex interplay between the many parameters precludes empiricism or rule-based decisions and necessitates the development of generic decision tools.

Since NEP maximization for **P**ositive-**E**nergy **B**uildings is attained thru **B**etter Contro**L** d**E**cisions **(PEBBLE)**, a control and optimization ICT methodology that combines model-based predictive control and cognitive-based adaptive optimization is proposed. There are three essential ingredients to the PEBBLE system: first, thermal simulation models, that are accurate representations of the building and its subsystems; second, sensors, actuators, and user interfaces to facilitate communication between the physical and simulation layers; and third, generic control and optimization tools that use the sensor inputs and the thermal models to take intelligent decisions. Building occupants have a dual sensor-actuator role in the PEBBLE framework: through user-interfaces humans act as sensors communicating their thermal comfort preferences to the PEBBLE system, and in return the PEBBLE system returns information with the goal of enhancing energy-awareness of the users.

PEBBLE Project: …Abstract

…Abstract

Moreover occupants' presence detectors and counting systems can provide additional information for the day to day activity of the building. The generality of the proposed methodology affords a universality that transcends regional, behavioral, environmental or other variations. For this reason, the PEBBLE system will be demonstrated and evaluated in three buildings possessing a variety of design and performance characteristics, located at different places across Europe.
Project PEBBLE is not just about improved energy-efficiency or generation-consumption matching, it is about utilizing harmoniously, and most effectively all installed systems in a building, taking into account human factors, and adapting the decisions in (almost) real-time as and when uncertainties occur.