Dynamic Calculation Methods for Building Energy Performance Assessment

Dynamic analysis and modelling techniques have been applied for many years to assess the solar and thermal performance characteristics of buildings and building components. However, producing accurate results which inspire client's confidence, can still be a problem.

The most prominent EU Directive is the EPBD-recast (2010) that requires that new constructed buildings are nearly-zero energy buildings (nZEB) and for which a significant part of the low energy use will be taken by renewable energy technologies. The consequence is a very dynamic character of energy flows in the building area, ranging from individual buildings up to urban area and cities. Renovation of the existing building stock demands for assessment before and after renovation. Dynamic assessment techniques are required to seek information about the energy flows from variable occupancy demand to variable renewable energy supply.

In the field of energy use in the building sector, support is needed from the academic world ranging from experimental work, energy consumption metering data, data analysis and building performance simulation.

The main objectives of the DYNASTEE Summer School are therefore:

- to train a common methodology to assess thermal characteristics of building components and to assess whole building energy performance;
- to bridge the gap between expertise from both physical and mathematical/statistical analysis and modelling practice and to set up cooperation with potential beneficiaries, by extending the available software tools and offering support services to a wider public;
- to transfer the necessary know-how to other areas that may profit from it, e.g. industry, designers, standards organisations (CEN, ISO), research networks (IEA, EU projects) and academics to support an extended network of building energy analysts.

The goal is not to promote a specific analysis or simulation tool but rather to transfer the knowledge on a common methodology. Reference data is required to develop methods and models.

DYNASTEE

Energy Performance of a Building *depends importantly on:*

Fabric, Structure, Geometrics, Orientation, Quality of Workmanship and of course the Climate zone

In addition the performance is defined importantly by the used energy systems for heating, cooling and ventilation and available energy resources.

CTSM-R

CTSM-R - Continuous Time Stochastic Modelling for R

CTSM is a tool for estimating embedded parameters in a continuous time stochastic state space model. CTSM has been developed at DTU Compute (former DTU Informatics) over several years. CTSM-R provides a new scripting interface through the statistical language R. Mixing CTSM with R provides easy access to data handling and plotting tools required in any kind of modelling.

CTSM-R is an R package providing a framework for identifying and estimating stochastic grey-box models. A grey-box model consists of a set of stochastic differential equations coupled with a set of discrete time observation equations, which describe the dynamics of a physical system and how it is observed. The grey-box models can include both system and measurement noise, and both nonlinear and nonstationary systems can be modelled using CTSM-R.

Continuous Time Stochastic Modelling for R or CTSM-R is a free, open source and cross platform tool for identifying physical models using real time series data. Visit www.ctsm.info for all information and how to install CTSM-R on your computer. Download the user guide from ctsm.info/pdfs/userguide.pdf. Both non-linear and non-stationary systems can be modelled using CTSM-R. By using a continuous time formulation of the dynamics and discrete time measurements the framework bridges the gap between physical and statistical modelling. CTSM-R is the latest incarnation of CTSM which itself can be traced back more than 30 years. CTSM-R extends the free and open source statistical platform R (www.r-project.org) thus combining the power of CTSM and the data handling, plotting and statistical features of R. CTSM was partly developed during the EU PASSYS project (1986 to 1989) and a number of follow up research project funded by EU. CTSM-R (2015) has been successfully applied to a wide range of data-driven modelling applications: heat dynamics of walls and buildings, dynamics of heat exchangers, radiators and thermostats, solar thermal collectors, building integrated photovoltaic systems and more.

It is possible to generate both pure simulation and k-step prediction estimates of the states and the outputs, filtered estimates of the states and, for nonlinear models, smoothed estimates of the states. Standard deviations of all state and output estimates are now also automatically provided. The CTSM modelling framework includes methods for model validation and for selecting the best model among a class of candidate models.

A CTSM-R model structure follows an object oriented style. The model is built by adding the mathematical equations one by one.

How to use CTSM-R is described in detail in the CTSM- R user's guide and reference manual.

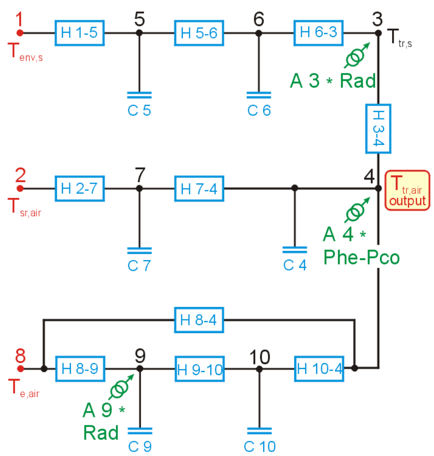
LORD-PEM

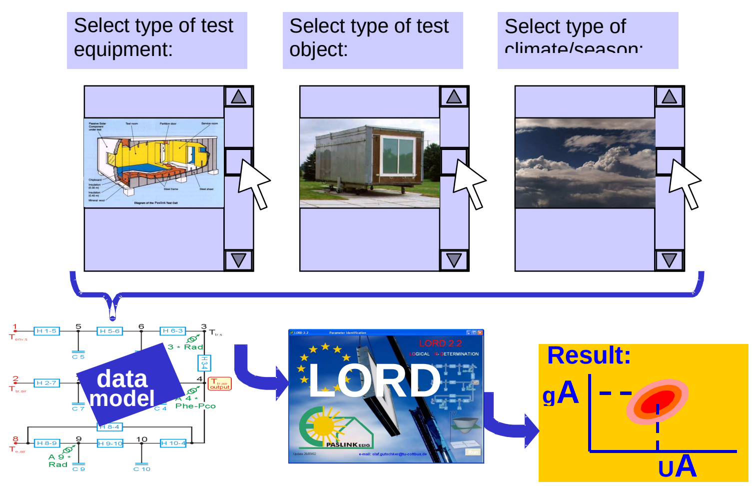
A new or renovated building envelope has to combine an optimised transmittance for thermal insulation and solar radiation. The assessment of energy performance and optimisation of the roof and facades may be studied at outdoor test facilities under real climate conditions. The evaluation of data from these outdoor measurements is much more complicated than the analysis of laboratory experiments due to uncontrolled and variability of the experimental conditions.
For that purpose software tools have been developed during several European research projects. Whereas CTSM-R builds upon Continuous Time models (see above) the software tool LORD builds on a lumped parameter (RC-network) model. Both methods are useful for most standard buildings and building components.

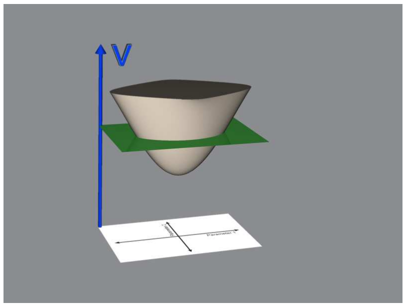
The original method implemented in LORD (a user-friendly software tool with graphical user interface) is the Output Error Method (OEM). A new quality in the analysis of this kind of outdoor experiments can be achieved by using advanced statistical methods. Therefore the software tool LORD has been extended lately with the Prediction Error Method (PEM) to make it more powerful. This tool is easy to use and specially adapted to the needs of this kind of real climate measurements. It will provide all the available statistical methods in an easy applicable way and will comprise instructions and data for self-training.

The development of the software tool has involved close cooperation of mathematicians and the intended users, building physicists.

The software is available to all who show interest in using this software and contact the distributor: www.dynastee.info







$$V = \sqrt{\frac{1}{N} \cdot \sum (T_{meas} - T_{calc})^2}$$

BESIM15

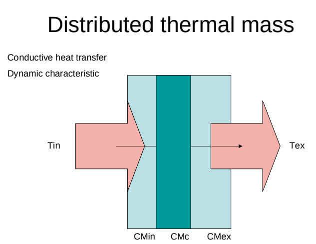
Benchmark tests for in-situ measurement evaluation methods.
- performance of system identification methods –

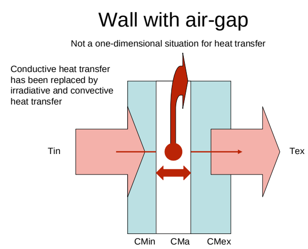
Objective: to evaluate dynamic calculation methods, e.g. the application of system identification techniques and to demonstrate the performance of different techniques applied to the analysis of experimental data from in-situ measurements of the heat transfer through a wall.

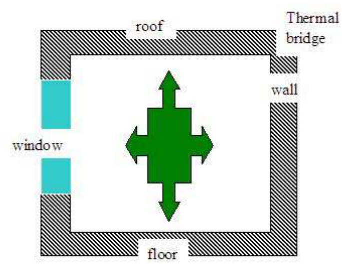
The approach considers three different type of in-situ measurements:

1. Thermal transfer by conduction only, e.g. through a solid wall component
2. Thermal transfer involving conduction, convection and radiation, e.g. an (air) gap wall that creates thermal convection and radiation exchange
3. Thermal transfer through a building envelope from indoor to outdoor environment, e.g. a whole building (impact of not measured thermal flows)

Details are presented in the JRC report for DG GROW; "*In-situ measurement standards for buildings and building components*" JRC92046 (2014).







A mathematical model represents reality however it is, by definition always a simplification of the true physical system. The user is responsible for defining the model and hence the simplification of it. There are ready to be used software tools, like LORD that allow the development of a model and in some cases allows also to choose a specific method. In other cases the modelling environment is offered, such as MatLab, TRNSYS, CTSM-R etc. So there is enough freedom to choose from.
It is therefore that benchmark tests should reveal the ability of the final method and model to analyse data from in-situ measurements correctly, within defined uncertainty limits.

Thermal transfer by conduction only.
The benchmark for the analysis of data from in-situ measurements, e.g. by conduction only, would consist of three exercises, describing a simple physical system (in this case a wall with two different temperature regimes on both sides and its resulting heat flow):

A - based on **simulated data** with known parameters for the user.
objective: the method can be tested and one may demonstrate its performance.
B - based on simulated data but the used parameters for generation are kept secret.
objective: the method should estimate the physical parameters and the accuracy of the estimates. The user should train the process of making a decision in model choice and hence reporting of the final result including an uncertainty assessment.
C - based on data from a **real in-situ experiment**.
objective: to identify a model (and the physical parameters) based on first part of the data series and to predict the heatflow for the second part of the data series.