DATA MANAGEMENT IN ENERGY SIMULATIONS

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1 Introduction

There are at least two big problems that prevent simulations from becoming a major part of the everyday design process. The first problem is related to the insufficient data exchange methods from the designers to the other participants. Already a very simple simulation requires a lot of input parameters to describe the building and the technical systems. Part of this data evolves during the design process and part of it has to be assumed as default values in some way. The designers have usually a lot of information that could be utilized in the simulations but the lack of knowledge (which data is important and in what format it should be delivered) prevents effective data exchange between different participants in the design process.

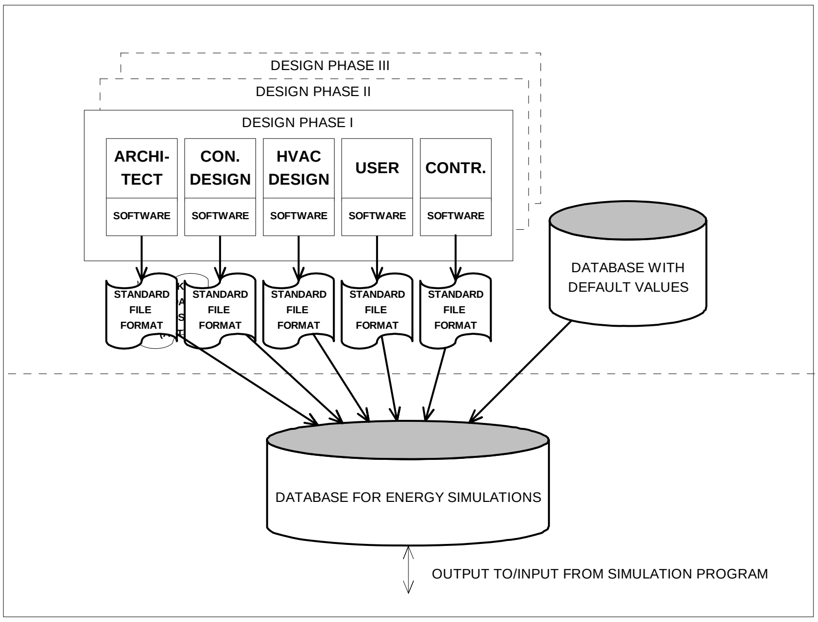

Figure 1. The simulation information flow in the design process (CON.=construction designer , CONTR. = contractor).

The second problem is related to the data that is not available from the designers. Resolving the lacking data requires a good knowledge about several disciplines (building physics, termodynamics etc.). The lack of expertise and the vague information about which data can be achieved from the designers and which data should be assumed, makes it difficult to market energy simulations as a standalone service. To make it even more difficult the default values are changed or updated in different design phases. Figure 1 shows how the design process participants should feed the energy simulation database with information about the project. There are many different building simulation programs on the market varying from simple spreadsheet programs to supercomputer CFD applications. For a HVAC designer it is often difficult to choose the right simulation tools, because there is a need for many kind of simulations during the building life cycle. The purpose of the simulation varies from demonstration to detailed dimensioning and design, and the requirements on the program vary as well.

The design phase (especially energy economical decisions) has a great influence on the building life cycle costs. To develop a building design data management model and suitable simulation tools is extremely important for energy efficient building design.

The problem with existing energy simulation programs on the market is that they have been developed for research purposes and are quite massive for normal design use. This is a problem especially in the beginning of a design, because the time for calculations is limited and the information is mainly based on defaults. Developing simulation tools, where the calculation may be done fast and the results are easy to put to an illustrative form, are needed for making good decisions.

The real-life design work sets some criterias for the data management system:

The same program throughout the building life cycle

The same program that has been a design tool could also be a FM (facilities management) tool. The only difference between the programs is the user interface. The FM personnel should have only a restricted access to program parameters.

The input data of the program is coded in only once

In the first design phases the input data is taken from libraries, and most of the values are just defaults. As the design process goes on, the data is corrected and made more accurate. The data coded into the program in early phases is utilized during the later phases. The main idea is: avoid redundancy and don't code the same data twice.

Link between design and FM database and simulation program input

The design database, facilities management database and the input database for simulation programs should contain the same information. Thus you will not end up with different values for the same data used in different tools.

Illustrative outputs

All outputs should be in an illustrative form. A chart or a pie tells much more to the client than a row of numbers. Don't transfer data to a client, transfer information instead, because data transfer is used for integrating IT-tools and not for people.

Outputs according to the needs of the designer

The designer should be able to select the needed output easily. If the program gives too much of output data, the important information may disappear in the huge amount of unnecessary diagrams.

Accuracy according the needs

The need for the accuracy of the calculations varies from phase to phase. It is unnecessary to calculate the room indoor air conditions with many decimals while comparing different HVAC systems. That would be only waste of time (and money). The accuracy of the 'calculation engine' should also be one parameter.

As the design goes on more and more data is defined and the amount of default values decrease. In the end of the project we will end up with a database that can be used for facilities management. The data input from the early design phases serve the building user through the whole life cycle of the building and makes the formatted data exchange more worthwhile.

2 Simulation Input Data Structure

Data that is available for energy simulations during the design process is described in this chapter. The items discussed must be seen in a larger context which is the use of data from many different sources for some particular calculations. The data is produced by varying amount of participants (client, architect, HVAC designers, construction designer, contractors, user of the building).

The entity hierarchy in the presented models is based on the Finnish Architect-RATAS -model. One aim of the work was to keep the models as simple as possible without reducing the applicability of the definitions to everyday design. The scope of the models is restricted to energy calculations although the data of course can be used also for other purposes.

An energy simulation database contains all parameters for a certain building or project. The simulation database contains both input and output values for the project. One aim of this approach is that it is always possible to track your calculation results back to the input values used in each simulation. Each simulation will be an own 'subproject' inside the database. This approach also gives possibilities to define common or open interfaces between different softwares and thus gives an opportunity for different companies to create own modules for the data exchange chain.

If there is a lack of some information in the data exchange files, the software would take care of defining default values (taken from a database with default values). Also these default values can then be tracked to the common database if necessary. This paper considers only the data exchanged from the designers. The full (database) model of course should deal with all the values required for starting and performing a simulation.

The designers considered in this paper are the architect, the HVAC designer and the construction designer. Other participants involved in the data definitions are the client, the user of a building and contractors. Bear in mind that these definitions are seen from one national design process view. The data all participants deal with is described in the following chapters. Today the designers hold project data locally with different softwares and tools. This paper does not pay any attention to what kind of tools are or should be used. This paper gives an example of what data should be defined in the different disciplines and what data from the used programs should be exported out (and in what format).

The method used to define the required data is product modelling. Product modelling gives possibilities to define things (related to the area of interest) more unambiguously than unstructured data definitions and thus give the developers and researchers an opportunity to discuss the data problem without semantical problems. The model can be used later as basis for writing programs to support automated data exchange. The product modelling does not prevent designers from using traditional ways of data exchange It is only one method to give the designers a chance to exchange the right information.

The building project is divided into entities, attributes and relations using the modelling language EXPRESS-G. In the following chapters the data model is divided into smaller parts due to the different design disciplines. Additionally the modelled entities and their attributes are explained in the text following the models.

The entities described for one designer may be defined or redifined also by other participants in the design process. This means that the designers do not 'own' an entity, they can only 'own' an instance of an entity. Main static entities (building, site) occur only as unique instances in a project but most other entities may have a number of instances defined by different designers. This model gives an example of who should be defining and what. Of course anything can be redefined in the common simulation database, but should then be updated as new calculation cases of the project. This will help to track the decision making process backwards and to see the influence of different decisions to the energy consumption.

2.1 Data Defined by the Architect

The architect usually makes the first needed definitions for the project and can be seen as the first participant in the data definition chain. From the energy simulations point of view the architect defines information regarding the building site, size and facades. The architect binds the outer limits of the building and at the same time the upper limits for the energy consumption. At this stage the influence from the other designers should be as big as possible. A fast and easy to use software could also be used by the architect himself.

Entities defined by the architect are described in figure 2. Attributes related to the entities are described in the text.

ARCHITECT

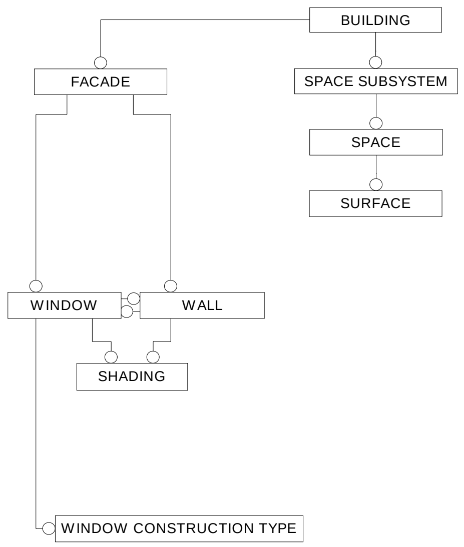

Figure 2. Energy simulation information defined by the architect.

Building
A building has a name which can be used as a unique identifier. Buildings are of a different types which helps to define usage rates and internal loads. Buildings can be divided into one or more space subsystems which have some common functionalities. The architect and the HVAC designer use different kind of subspacing. A building has facades facing to the different directions which affects the amount of solar gains entering spaces. A building is situated on a building site which helps to define weather data. The size of a building can be defined eg. as square meters.

Space subsystem
A space subsystem defines functional (architectural) requirements for a group of spaces. A space subsystem can also be technical which is defined by the HVAC designer. A space subsystem has a name which can be used as a unique identifier. A space subsystem is divided into one or more spaces. A space subsystem is part of a building.

Space
A space is normally equal to a room. A space has a name which can be used as a unique identifier. Spaces are parts of one or more space subsystems. A space is bounded by surfaces. The shape, room height and floor area of a space are used for geometrical definitions. The indoor air quality targets help in later stages to define temperature set points for the technical systems. The heat capacitance in a space is affected by furniture.

Surface
A surface is the way an architect sees the space boundaries. A surface has been originated from architect definitions and can be integrated also to the HVAC designers model although there is now actual connection to energy aspects. The connection to energy calculations is that a surface has a wall or a window on the outer side. A surface has a name which can be used as a unique identifier. A surface has also a direction, which can be to the outside or to adjacent spaces. A surface has also an area which is used for heat exchange calculations.

Facade
A facade is the building surface seen from outside. A facade has a name which can be used as a unique identifier. A facade consists of one or more walls and windows. A facade is faced to a certain direction which helps to define solar gain impact on spaces behind the facade.

Wall
A wall can be an outside wall or an inside wall. A wall has a name which can be used as a unique identifier. An outside wall is part of the building facade from an architect point of view. A wall may be connected to one or more windows. A wall is made out of a construction type. A wall may also have some shading from overhangs close to the wall. A wall has height and width values. The type of a wall can be eg. outside wall, inside wall, roof or intermediate floor.

Window
A window has a name which can be used as a unique identifier. A window is part of the building facade from an architect point of view. A window may be connected to one or more walls. The glass area of a window is defined by the height and width of the glass area. The frame area is defined by the height, width and thickness of the frame construction. The slope of the window is used for solar gain calculations. Information about blinds affect the calculations of solar gains.

Shading device

A shading device is an overhang construction around a window or close to a wall. A shading device has a name which can be used as a unique identifier. The type of a shading device gives information about how the overhang is placed in relation to a window or wall. Offsets from windows and walls in different directions have to be defined in order to model the overhang exactly.

Window construction type
A window construction type is used in the same way as a wall construction type. A window construction type has a name which can be used as a unique identifier. Descriptions concerning a window construction are the number of glasses, a film used for sun protection, the area of glass and frame and any information affecting to the solar transmittance through the window.

2.2 Data Defined by the HVAC Designer

The HVAC designer is the participant who will do most of the energy calculations. The HVAC designer has several reasons to make thermal calculation (eg. to size technical systems and define energy consumption targets). As can be seen by comparing the HVAC model in figure 3 with the other models of other participants in the design process, the HVAC designer deals with more information than anyone else. The main entities for this discipline are entities related to the space entity. The HVAC designer views the windows and walls from another point of view than the architect. The main difference from the architectual model is that everything is here space orientated when it is more building concentrated in the architect's model. The HVAC designer will take inputs from the architect's data definitions as described in the previous chapter, from the construction designer and from the user of the building. Entities defined and used by the HVAC designer is described in figure 3. Attributes related to the entities are described in the text.

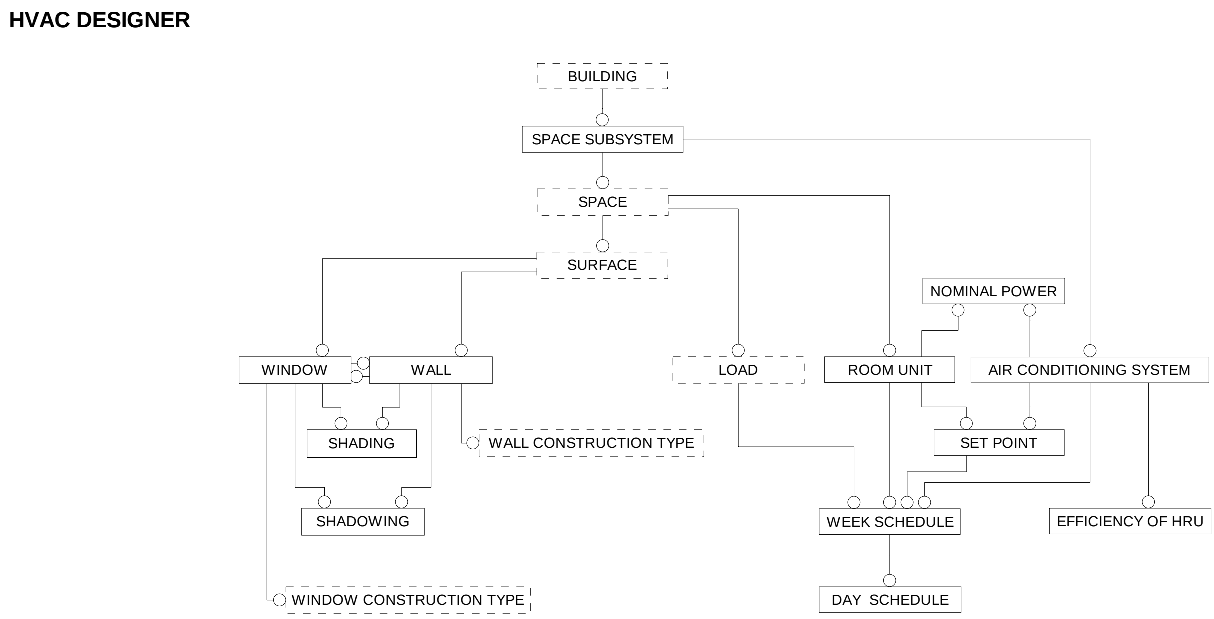

Figure 3. Energy simulation information defined and used by the HVAC designer (entities marked with dashed lines defined by other designers).

Building
The HVAC designer will re-use the building instance as defined by the architect. As the HVAC designer defines new technical space subsystems, he or she will add data to the building instance.

Space subsystem
The HVAC designer will add instances of technical space subsystems to the data definitions. A space subsystem has a relation to an air conditioning system.

Space
The HVAC designer will re-use the space data defined by the architect. The added data is information about which technical space subsystem the space belongs to, which room unit serves the space and information about internal loads. Also an estimation about the infiltration rate and additional heat capacity information is needed.

Surface
The HVAC designer will re-use surface information provided by the architect. Surface information is used to track down the wall constructions around a space. The entity surface is not actually needed by the HVAC designer but has been added to the model to keep the model structure consistent with the architect model.

Wall
For the HVAC designer a wall is bounding spaces but for an architect walls are bounding buildings. This results in different relations from a wall to the building as we see if we compare figures 2 and 3.

Window
The HVAC designer and the architect also view the windows in different ways. The area for windows for a HVAC designer has to be defined for each space separately but in the architect's model the area stands for the whole facade. Also the direction attribute for the HVAC designer occurs at the window level and in the facade entity for the architect.

Load
A load entity defines internal loads in the building such as occupancies, lights and equipment. A load has a name which can be used as a unique identifier. The type of the load helps to describe how the load is divided into radiation and convective parts. Moisture loads should be given for human occupancies. All loads vary according to week or year schedules.

Week schedule
A schedule defines how different technical systems and internal loads vary with time. The basic schedule cycle is one week. A week schedule has a name which can be used as a unique identifier. The same week schedule can occur for several systems and loads. A week schedule consists of seven day schedules. Also set points may vary in relation to a week schedule.

Day schedule
A day schedule describes how the load usage varies during one day. A day schedule has a name which can be used as a unique identifier. The day information is one attribute for the day schedule. Usage schedule is described with attributes time of day and usage rate.

Air conditioning system
An air conditioning system defines the type of a centralized air handling unit used. The type can be eg. constant air volume system, variable air volume system or cooled beam system. The air conditioning system is defined for each technical space subsystem. An air conditioning system

has a name which can be used as a unique identifier. An air conditioning system is run according to a week schedule and may have set points for temperature, humidity and air flow rates. The idea of the modelling approach used is to give just some common values about the system and its components ie. heating and cooling nominal power and set points for temperature or humidity, nominal efficiency of heat recovery and surface temperature of the cooling coil. It is up to the simulation software to provide more exact module parameters for the mathematical models in the simulation eg. through libraries connected to the simulation program.

Room unit
A room unit is for example a re-heating/cooling coil or a fan coil. It is not neccessarily physically situated in a room (space) but it has to serve only one or a few rooms or spaces. A room unit has a name which can be used as a unique identifier. A room unit is used according to a week schedule and has a set point (usually the room temperature set point) and a dimensioning value named a nominal power.

Set point
A set point can describe temperature, humidity or air flow rate. A set point has a name which can be used as a unique identifier. A set point is used for defining parameters for an air conditioning unit or a room unit. A set point may be time dependent.

Nominal power
The entity nominal power describes the performance of a HVAC component such as a heating or a cooling coil. A nominal power instance has a name which can be used as a unique identifier. Nominal power instances can be defined for air conditioning systems and room units.

Efficiency of the heat recovery unit
The entity efficiency of a heat recovery unit describes the nominal effeciency for the device. An efficiency value has a name which can be used as a unique identifier. The efficiency value is part of the central air conditioning system. The efficiency can stand for temperature or humidity depending on the type of the heat recovery device.

Shading device
A shading device is consistent with the architectual model but is here used to describe more detailed shading such as shading for a certain window. A shading device has a name which can be used as a unique identifier. Attributes of shading devices are depth, width and slope.

2.3 Data Defined by the Construction Designer

The construction designer provides data about materials used in the constructions. From the modelling point of view, the construction designer deals with the information 'behind' the surfaces. The amount of information from the construction designer is rather small, but the information is nevertheless important for energy calculations. Entities defined and used by the construction designer is described in a figure 4. Attributes related to the entities are described in the text.

CONSTRUCTION DESIGNER

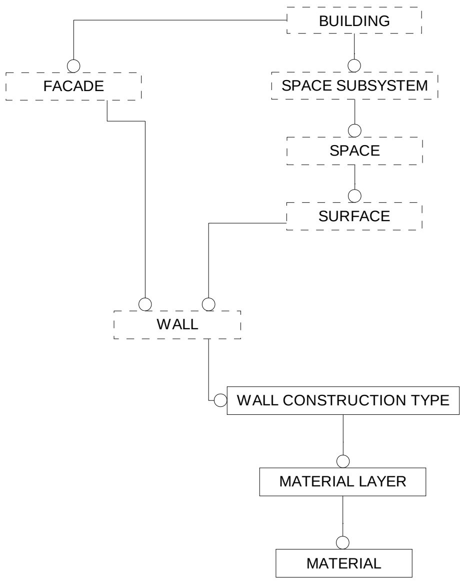

Figure 4. Energy simulation information defined by the construction designer (entities marked with dashed lines defined by other designers).

<u>Wall construction type</u>
A wall construction type is a common library type for walls, roofs, floors. It is used as a reference construction for several wall instances in the building. The idea in this approach is that you only have to change the properties of one wall construction type to change the wall properties of the whole building. A wall construction type has a name which can be used as a unique identifier. The wall instances which are linked to the wall construction type will be created by the architect (facade links) or the HVAC designer (space links). A wall construction type consists of material layers and may have a product name (prefabricated walls). U-value and massiveness information are used in the early design stages.

<u>Material layer</u>
A material layer describes one layer in the construction type. A material layer has a name which can be used as a unique identifier. A material layer is made of some material which has a thickness. Material information together with the thickness value can represent a typical product with a product name on the market.

<u>Material</u>
A material entity holds the basic thermal properties such as conductivity, capacitance and density. A material has a name which can be used as a unique identifier. A material can be described by a product name which can be used as a reference to supplier catalogues.

2.4 Data defined by the User of the Building

The user of the building defines data related to internal heat loads in the building. Typically the HVAC designer will gather this information for energy simulations.
Entities defined by the user of the building are described in figure 5. Attributes related to the entities are described in the text.

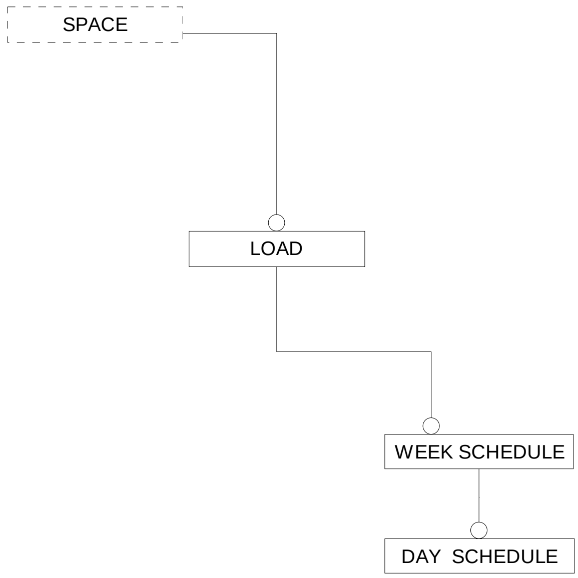

Figure 5. Energy simulation information defined by the user.

Load
A load entity defines internal heat loads in the building such as occupancies, lights and equipment. A load has a name which can be used as a unique identifier. The type of a load helps to describe how the load is divided into a radiation and a convective part. Moisture loads can be given for human occupancies. All loads vary according to a certain week schedule.

Week schedule
See HVAC designer.

Day schedule
See HVAC designer.

2.5 Conclusion

Describing the design process from an energy simulation point of view results in different models for two major design disciplines ie. the architect and the HVAC designer. It also integrates information provided by the construction engineerer and the user of the building. Figure 6 shows all the entities defined in the previous chapters.

MAIN SCHEMA

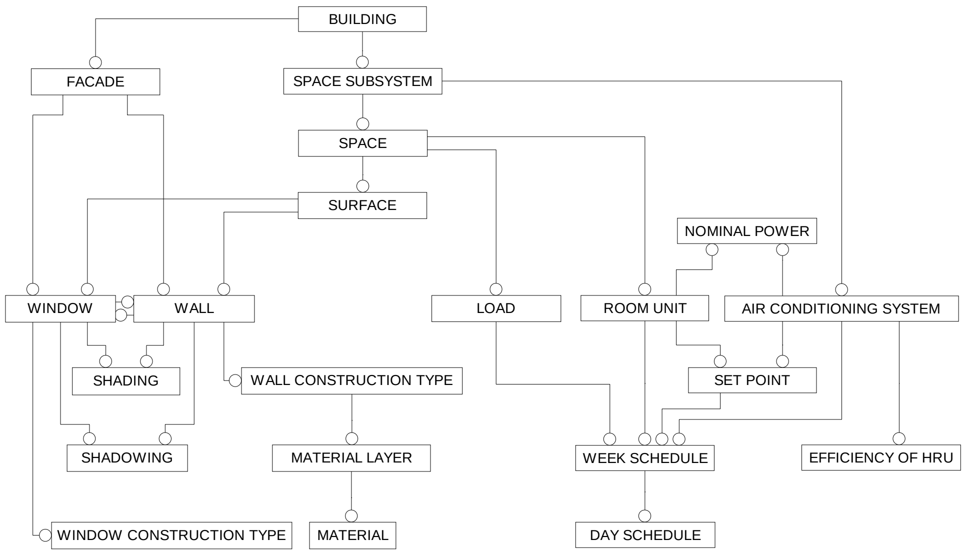

Figure 6. Information defined for energy simulations during the design process.

These models are only conceptual and an implementation model will be much more detailed. Nevertheless these models contain most of the critical information needed to carry out energy simulations both for individual spaces and for whole buildings with air conditiong systems. After implementing a model like the presented into a working data management system, the next problem will be to collect default data for different attributes. This seems to be a big problem to resolve in the future. The lack of widespread and accepted library sources for simulation data will prevent thermal simulation programs from being used in the every day design.