Evaluation and Comparison of Various Calculation Zone Analysis for Dynamic Simulation Software's

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Abstract-- Since July 2009 it is compulsory for a new or major renovation building project to meet the requirements set by Estonian Government regulation nr. 258 „The Minimum Requirements for Energy Efficiency". Conformity of the building to the minimum requirements for energy performance shall be inspected by way of an energy calculation upon standard use of a building, utilising primary data provided for in this Regulation regarding outdoor and indoor climate, periods of use and operation of the building and its utility systems, free heat, and air-tightness of the building. Other primary data required for the calculation shall be taken from the construction design documentation of the building. Unfortunatelly the regulation does not state in how many different calculation zones exactly should the dynamic simulation calculation be accomplished. This article reports on analysis of evaluation carried out in Tallinn University of Technology how the implementation of the regulation has taken effect as well shows how the lackage of information regarding the calculation zones may influence the calculation results. As the results show there are severe problems with application of this regulation, concerning the regulation itself, as well as the shortage of information and knowledge to use complicated dynamic simulation softwares. Finally sugestions regarding how to improve the regulations have been given.

Keywords: Energy simulation software, Energy efficiency, Energy Regulation, Simulation

I. REGULATION 258

Regulation nr 258 establishes minimum requirements for the energy performance of buildings and the primary data and calculation methods required for verification of the conformity thereof. The scope of application of this Regulation includes residential buildings and other buildings with controlled indoor climate which are under construction or which undergo major renovation in which indoor climate requirements primarily result from human applications and energy is mainly used for ensuring indoor climate, for heating domestic water and for using domestic and other electrical appliances.

According to the purpose of buildings, requirements shall be imposed on the following buildings:
1) residential buildings: small houses (residential buildings with one or two apartments, terraced houses with three or more apartments according to purpose); apartment buildings (residential buildings with three or more apartments, facilities of social welfare institutions and hostels according to purpose);
2) other non-residential buildings: office and administrative buildings; commercial buildings (hotels, other accommodation and catering facilities, trading and service facilities, with the exception of office buildings); public buildings (recreational, educational and other public buildings, with the exception of health care facilities and indoor swimming pools) and transport facilities (with the exception of garages); health care facilities (hospitals and other medical buildings, with the exception of social welfare institutions); indoor swimming pools.

If a building has multiple purposes, each part of the building which has a separate purpose and the heated space of which exceeds 10% of the heated space of the entire building, shall be determined an energy performance ratio corresponding to the purpose. Zones with an area below 10% shall be included in the composition of other zones irrespective of purpose. Maximum permitted energy performance ratio of a building is the weighted average energy performance ratio of the purposes of the parts of the building calculated on the basis of heated space.

II. ENERGY PERFORMANCE RATIO

Minimum requirements for energy performance shall be the limit rates of summary energy use of existing buildings and buildings under construction, taking account of the usage purpose and the technical characteristics of the buildings, or requirements for utility systems, utilised for measuring the characteristics related to efficiency and their functioning thereof. The conformity of a building to the minimum requirements for energy performance shall be assessed on the basis of the construction design documentation in the course of designing the building. Minimum requirements for energy performance shall be expressed as an energy performance ratio, which is the reference summary weighted specific use of supplied energies upon standard use of a building. The energy performance ratio reflects the complete energy use of the building for ensuring indoor climate, for heating of domestic water and for using domestic and other electrical appliances.

The energy performance ratio of buildings under construction shall not exceed the following limit values:

1) annually 180 kWh per square metre for small residential buildings (incl. semi-detached houses and terraced houses);
2) annually 150 kWh per square metre for apartment buildings;
3) annually 220 kWh per square metre for office and administrative buildings;
4) annually 300 kWh per square metre for commercial buildings, hotels, other accommodation and catering facilities, and trading and service facilities;
4^1) annually 300 kWh per square metre for public buildings and recreational buildings;
4^2) annually 300 kWh per square metre for educational buildings and research facilities (with the exception of student hostels, libraries and clinics);

5) annually 400 kWh per square metre for health care facilities;
6) annually 800 kWh per square metre for indoor swimming pools.

(The energy performance ratio of buildings undergoing major renovation shall not exceed the following limit values:

1) annually 250 kWh per square metre for small residential buildings (incl. semi-detached houses and terraced houses);
2) annually 200 kWh per square metre for apartment buildings;
3) annually 290 kWh per square metre for office and administrative buildings;
4) 390 kWh per square metre for commercial buildings, hotels, other accommodation and catering facilities, and trading and service facilities;
4[1]) annually 390 kWh per square metre for public buildings and recreational buildings;
4[2]) annually 390 kWh per square metre for educational buildings and research facilities (with the exception of student hostels, libraries and clinics);
5) annually 520 kWh per square metre for health care facilities;
6) annually 1,000 kWh per square metre for indoor swimming pools.

Energy performance ratio of the building shall be calculated if conformity to the minimum requirements for energy performance is proven by calculation. In order to calculate the energy performance ratio, the products of weighting factors of supplied energy (i.e. utilised electrical energy and energy content of utilised fuels) and weighting factors of energy carriers shall be summed up. The supplied energy use shall be calculated pursuant to the requirements provided for in this Regulation.

The weighting factors of energy carriers shall be as follows:
1) 0.75 for fuels based on renewable raw material (wood and wood-based fuels and other bio-fuels, excl. peat and peat briquettes);
2) 0.9 for district heating;
3) 1.0 for liquid fuels (heating oils and liquefied gas);
4) 1.0 for natural gas;
5) 1.0 for solid fossil fields (coal, etc.);
6) 1.0 for peat and peat briquettes;
7) 1.5 for electricity.

The fuel energy content shall be calculated via calorific value. The lower calorific value provided by suppliers or the data provided for in Annex 1 of this Regulation shall be used as calorific value.

II. REQUIREMENTS FOR SUMMER-TIME ROOM TEMPERATURE

The requirement for summer-time room temperature shall be declared fulfilled if the room temperature in the period of 1 June to 31 August does not exceed the limit temperature provided for in the Regulation (cooling temperature setting) by more than 150 degree hours (°Ch) in residential buildings and by more than 100 °Ch in other buildings provided.

Cooling system in the building may be necessary for fulfilling the requirement for summer-time room temperature. In such a case the energy calculation must include the net energy demand for cooling of rooms and the energy use for the cooling system. A description of the cooling system shall be required in design only for the scope necessary for performing the energy calculation. Actual construction of the cooling system shall not be required.

In non-residential buildings, the temperature inspection of rooms shall be conducted by simulation calculation of standard rooms. In order to take account of the room temperature exceeding the determined value due to temperature adjustments. Room temperature inspection of residential buildings may be performed by simulation calculation of standard rooms or by utilising simplified aid materials, e.g. graphs developed for that purpose. Small houses shall be exempt from temperature inspection if all of the following conditions are simultaneously fulfilled:
1) sunshade glass with a solar factor of $g \leq 0{,}4$ or other solutions to equivalent effect are utilised on window surfaces exceeding one square metre in exterior walls towards west and south;
2) the area of the glass part of living room windows and bedroom windows towards west and south comprise maximum 30% of the area of the exterior walls towards west and south;
3) the area of opening windows in living rooms and bedrooms comprises at least 5% of the floor area of these rooms.

Regardless of the building's location, the energy calculation and inspection of summer-time room temperature shall be performed utilising the Estonian reference year for energy calculations. The reference year represents the typical outdoor climate of the past three decades (1970–2000) and is thus not suitable for calculations of heating demand. The reference year may be used for calculations of cooling demand.

III. INDOOR CLIMATE

(1) Energy calculation shall utilise the data provided for in Annexes to Regulation 258 regarding reference temperatures, air flow volumes of ventilation, and other parameters of indoor climate. If the designed air flow volumes exceed the values provided for in Annexes to this Regulation or if the room temperature is higher upon heating or lower upon cooling when compared to the values provided for in Annexes to this Regulation, the energy calculation may be performed on the basis of the data stated in the construction design.

(2) Room temperature settings for standard use are provided for in Annex to this Regulation too. Simplified calculations with constant room temperature shall utilise the settings provided for in Annex 2 to this Regulation as room temperature (e.g. in residential buildings 21°C for heating and 27°C for cooling). Dynamic calculations shall utilise these values as temperature settings for heating and cooling thermostats. In case of buildings without a cooling system,

the cooling temperature setting shall mean a limit temperature with requirements provided for in subsection 4 (1) of this Regulation.

(3) Air flow volumes during use of ventilation upon standard use and reference floor areas of standard rooms per person are provided for in Annexes 3 and 4 to this Regulation. In case of non-residential buildings outside the period of use, the air flow volume of ventilation in off-hours mode shall generally be 0.15 l/(cm^2).

(4) Air flow volumes of residential buildings shall be calculated as follows, utilising values provided for in Annex 4 to this Regulation:
1) calculating the summary air flow volume on the basis of the closed net space of the entire building (overall air replacement pursuant to Annex 4);
2) calculating the summary air flow volume on the basis of residential premises (floor area of living rooms and bedrooms) and adding the air flow volume of non-residential premises calculated on the basis of overall air replacement;
3) selecting the higher of the previous two calculated air flow volumes and utilising it as the summary air flow volume, whereas the air replacement rate calculated on the basis of the summary air flow volume shall not exceed one air replacement per hour;
4) selecting and calculating extractions so as to ensure that their sum equals the summary air flow volume.

(5) The air flow volumes provided for in Annexes 3 and 4 to this Regulation shall be utilised as maximum air flow volumes for ventilation systems of non-residential buildings with variable air flow volumes adjusted according to the air quality (regarding carbon dioxide (CO_2) levels or regarding a combination of e.g. CO_2 and temperature or humidity levels). If a system with variable air flow volume is used for cooling purposes, the maximum air flow volume shall be determined on the basis of cooling demand. The minimum air flow volume and the control graph of the ventilation shall generally be chosen so as to ensure that the maximum concentration of 1,000 ppm CO_2 is not exceeded, whereas a reference concentration of 400 ppm in outdoor air shall be utilised.

IV. ENERGY CALCULATION

Energy calculation shall not assume detailed zoning of buildings. Small residential buildings and buildings with a single purpose may be calculated as a single zone. Larger buildings shall be divided into the required number of zones according to purposes and periods of use. Inspection of summer-time room temperature shall be performed for room types with the most free heat (presumably rooms at southern or western side of the building or with large glass surfaces) or with estimated continuous presence of room users.

Calculation of summer-time room temperature for residential buildings shall be performed for at least one bedroom and living room conforming to the provided requirements. Calculation of summer-time room temperature for other buildings shall be performed for all room types (e.g. open and closed offices, classrooms), with a single room conforming to the provided requirements being selected to represent each room type.

V. STAGES OF ENERGY CALCULATION

Energy calculation shall include at least the following stages:
1) calculation of net energy demands, including calculations of net energy demand for heating of rooms, net energy demand for heating ventilation air, net energy demand for heating of domestic water, and net energy demand for cooling of rooms;
2) calculation of summer-time room temperatures;
3) approximate calculation of the heating system on the basis of the efficiency factor of the heat source or the thermal factor of the heat pump system and the electricity consumption of the auxiliary equipment;
4) approximate calculation of the heating system on the basis of the efficiency factor of the heat source or the thermal factor of the heat pump system and the electricity consumption of the auxiliary equipment;
5) approximate calculation of the cooling system, taking account of the condensate losses and heat losses of the cooling system and the cold production;
6) calculation of electricity consumption of the electrical system according to the primary data of lighting and equipment use;
7) presenting of calculation results as the building's summary annual energy use pursuant .

VI. REQUIREMENTS FOR CALCULATION SOFTWARE

The calculation software utilised for energy calculations shall have the following features:
1) dynamic calculation of the building's thermal exchange;
2) climate processing module, allowing importing the Estonian reference year for energy calculations with its original level of precision and calculating the hourly values of solar radiation on surfaces and the shadow zones;
3) possibility to model heat recovery of a ventilation system and preferably possibility to model ventilation, heating and cooling systems at the level of their main components and functions (e.g. inspection of heat exchanger icing, accounting for condensate on a cooling battery);
4) use of actual room temperatures in calculations and preferably possibility to model control graphs (e.g. calculation of heat transmission in ventilation according to the changing room temperatures together with controlling the heat recovery and the incoming air temperature);
5) the calculation software must be validated pursuant to the relevant standard.
(2) All calculation software programs conforming to the above stated requirements may be used for energy calculations.
(3) Energy calculations for residential buildings may also be performed by software utilising simplified calculations per months or per degree days.

VII. PROBLEM DESCRIPTION

In co-operation with State Technical Supervision Authority altogether 13 buildings were selected. Enquiry showed that only 3 project`s energy consumption calculations where done with suitable simulation software. Furthermore, 1 project calculation out of the 3 was not done according to decree, using project based input values and not standard profiles according to the decree.

The other calculations were accomplished by simulation software BV2. The reason behind using inappropriate simulation program was the user friendliness of the program BV2 with its easy-to-understand Estonian manual. Also it is the only available simulation software without any fee. At the same time, the appropriate simulation programs where considered very sophisticated and difficult to understand with their foreign (English) language manual.

These two project calculations that qualified for calculation check analysis where checked. Howevwer the original calculations and out check calculation results differed about 35%. The reason behind that is that different num,ber of zones were used in check calculations compared to original calculations.

VIII. SOFTWARE COMPARISSON

The aim of the software comparison was to compare program BV2 with other softwares that currently are accepted by regulation BV2. Secondary aim but not least was to compare the calculation results considering various calculation zones mainly comparing one calculation zone to twenty calculation zones. Totally five simulation softwares were compared. The programs were IDAice, Riuska, BSim, VIPenergy and BV2. The comparing calculations of the calculation software BV2 were carried out by 9 people, among them academics, PhD candidates and post-graduates of Tallinn University of Technology. A number of them have long experience in working with the simulation programs. Calculations with each program were performed by several people in order to avoid inaccuracies. In case BV2 would give similar results to other programs outcome suggest that BV2 to be accepted by calculations.

Five story building was chosen for calculations. The calculations besides zone investigation were accomplished to analyze the consumption of heating, cooling and ventilation. During the calculations multiple parameters were investigated, the size of the windows, the solar factor of the windows, the influence of the orientation etc. Also the purpose of the building was varied. The calculation was accomplished for office, hotel and/or school. Figure 1 illustrates the building shape and different glazing portions that were used for the calculation.

To evaluate the different programs' accountability for internal and solar loads in simulations, the following configurations were performed: 1) a building without internal loads (from equipment, people, lighting); and 2) a building without windows and non-operating ventilation system.

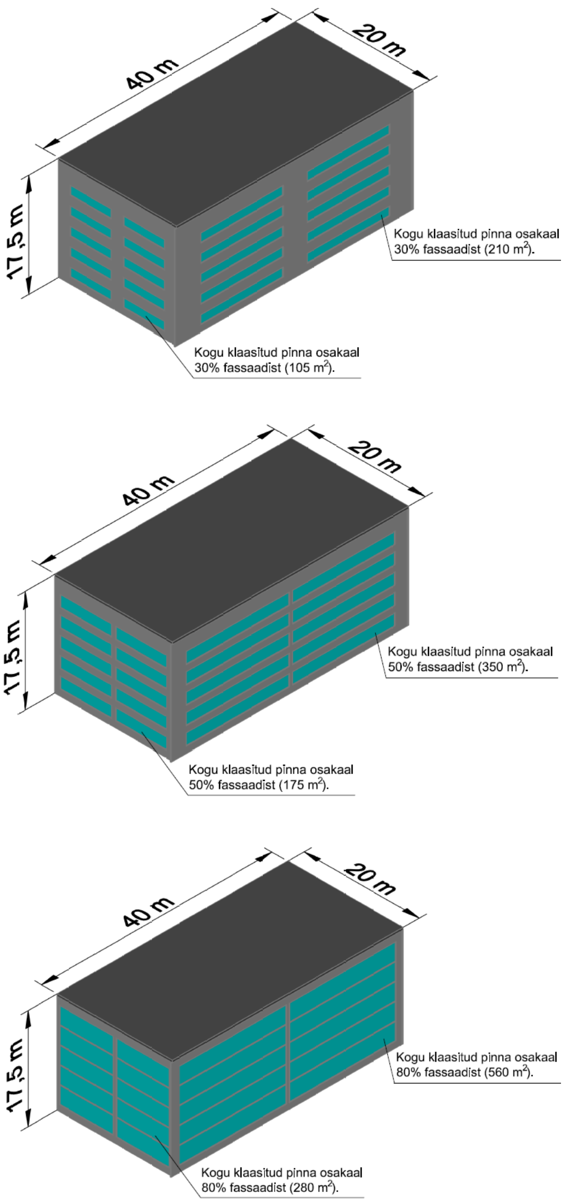

Fig. 1 Buildings used for calculations

Figure 2 represents the solar radiation effect on building heating energy consumption. The building is considered to be light and has windows with a g-value of 0.5. While for BSim the difference is in every case around 1/3, for other programs the results differ more with larger window area. For IDA-ICE the results are 7-20% larger, and for VIP Energy the variation is from -7 to 12%.

In Figure 3 we can see the effect of solar radiation on room cooling energy consumption and the difference of programs in comparison with BV2. Building type is as stated in the previous paragraph. This time other programs give lower energy consumption values, ranging from -35 to -65%. Again there is a very large variation, but it must be noted that for IDA-ICE it is -35% for all cases, and close to -40% in all cases for VIP Energy. BSim is the only program with a noticeable variation, from -46 to -65%.

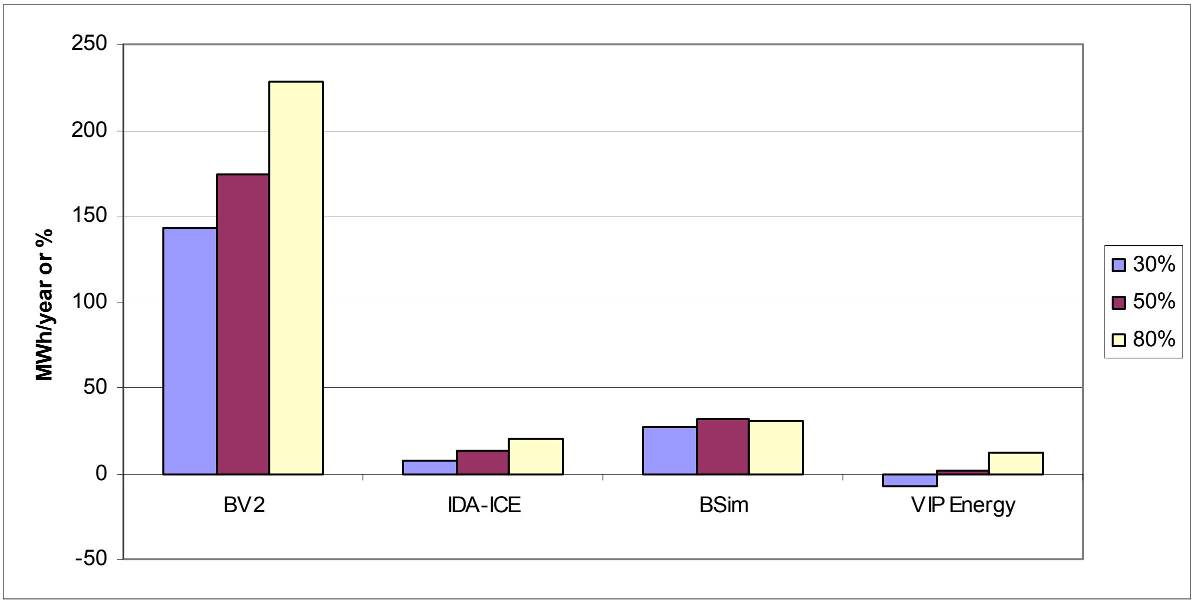

Fig. 2 The effect of solar radiation on room heating energy consumption for BV2 [MWh/y] and % difference with other programs.

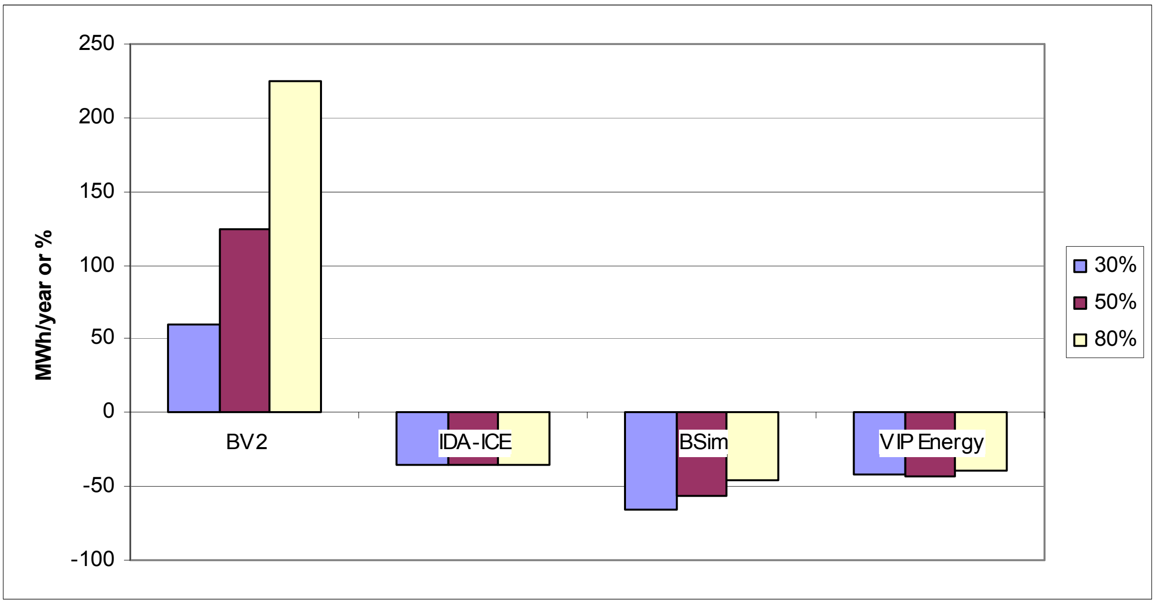

Figure 3. The effect of solar radiation on cooling energy consumption [MWh/y] and % difference with other programs.

IX. NUMBER OF ZONES

Number of simulations were carried out to compare 1 and 20 zone simulation model results. This is important to evaluate the need of using multizone model, which usually means longer calculation time, while not all programs offer the possibility to enter multiple zones. Also more zones will need higher user experience and knowledge, making model more complex and with that may not support the idea of making simulation programs available for everyone. Meaning that with complex models it might be too difficult for persons without proper education in the field to perform simulations.

Next 2 figures represent the office building configuration with 50% windows per facade area and with g-value of 0,5. Other input data e.g. ventilation rate, internal heat gains etc. are according to the decree.

Results on effect of zone numbers on heating load are shown in Figure 3. BV2 has no option of entering multiple number of zones, which is why figure shows same results for both 1 and 20 zones. VIP Energy also does not allow entering multiple zones, although in that program extra internal constructions were added. Results from programs allowing multiple zones show at most 10% difference when comparing to single-zone model. Thus, expecting multiple-zone model to be more exact, 1/10 of result accuracy can be assigned to a simple decision over zone numbers.

Looking at cooling load calculations, Figure 3, the effect of zone numbers is much larger. Still BV2 and VIP Energy results can not be taken very seriously for 20 zone case. Thus the analysis has to be based on 3 other programs. There is a huge, up to 85%, difference for Riuska and quite high for IDA-ICE as well (60%) whether 1 or 20 zones are used. BSim results differ around 10% as do VIP Energy's depending on number of zones.

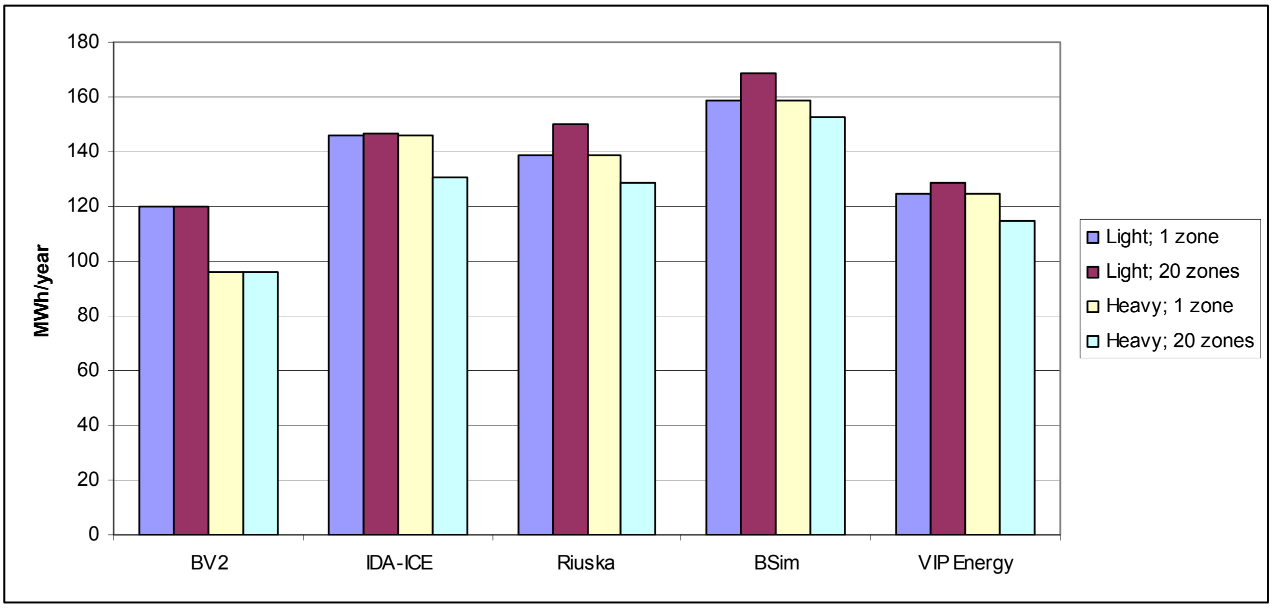

Fig. 3 Heating load depending on zone numbers

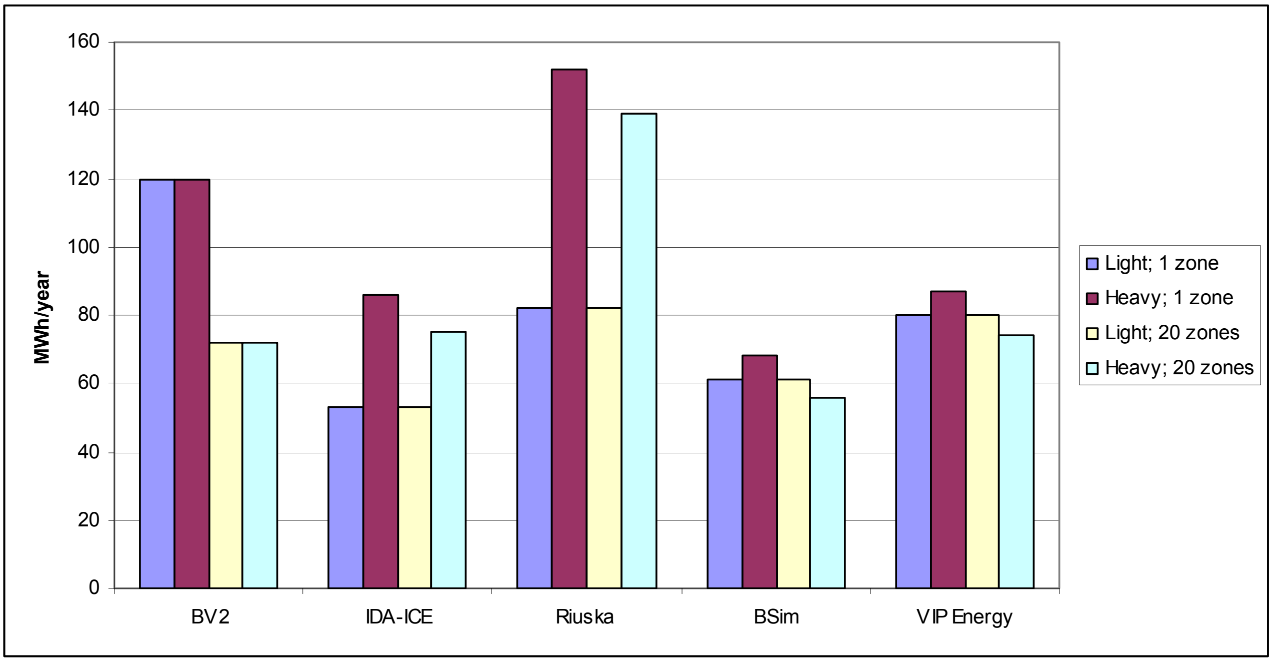

Fig. 4 Cooling load depending on zone numbers.

To conclude on importance of zone numbers, it must be clear that it makes a difference. Although for heating energy consumption the effect is quite small, it is determining factor for cooling load! Especially sensitive about zone numbers are Riuska and IDA-ICE. Using those programs it is advisable to use multi-zone models for more accurate results.

Following Figure 5 shows the effect of zone numbers on ventilation air heating coil. From that it can be seen that the effect of building construction type is ineligible, but for some programs the number of zones is important. Obviously 1-zone results for BSim are not correct, also VIP Energy results seem unreasonably low.

For cooling coil energy consumption the difference is smaller, varying up to 15% for IDA-ICE, while other programs show the same result for single- and multi-zone simulations.

It can be concluded that calculation engines for different programs differ to quite some extent. For certain programs the need to use multi-zone models is obvious.

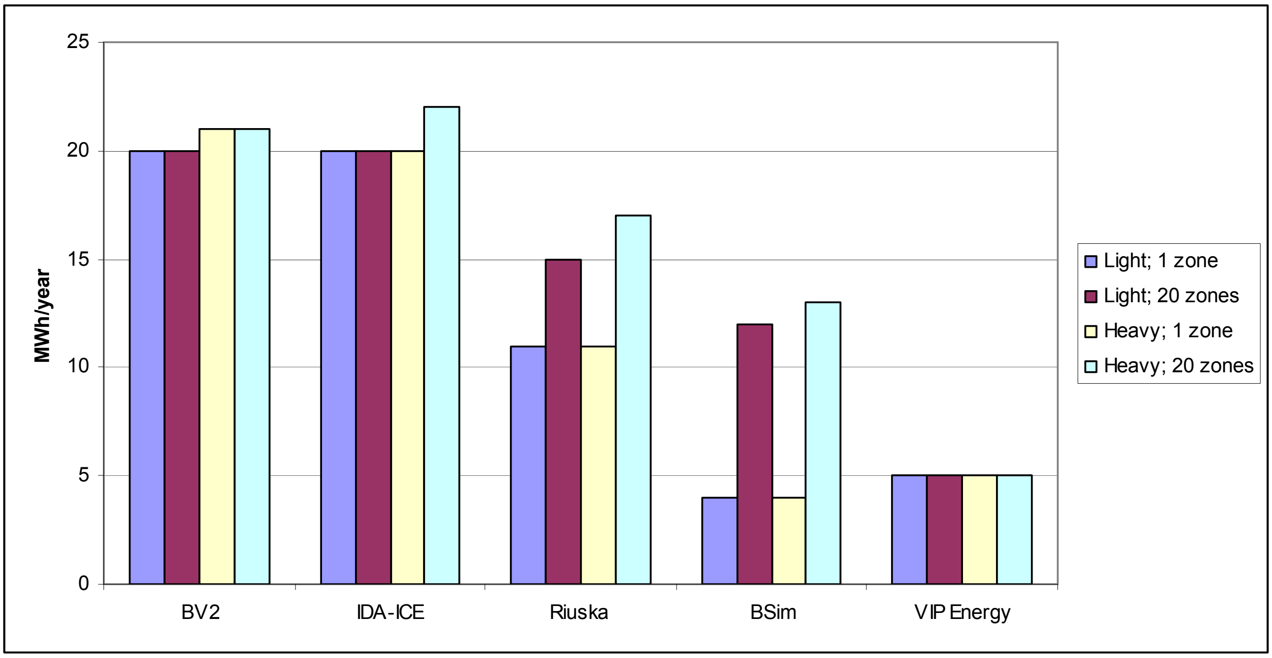

Fig. 5 Ventilation air heating coil energy consumption.

Totally about 2000 simulations were accomplished. The comparing calculations showed that different programs gave quite different results. In some cases the results different even in many times. Due to the fact that the results differed to such an extent it is hard to claim whether BV2 is better, more accurate and adequate than other programs. BV2 has certain shortcomings and simplifications. In most cases the results of BV2 give a lower number of the energy used for heating and a higher number for cooling spaces than the average result of compared

programmes. In order to use BV2 for proving whether the energy efficiency requirements have been met, a few concession have to be made such as presenting clear and adequate overviews of the contradictions and problems in the work in question and if needed also correcting the software.

According to the researches, analyses and calculations carried out for this work, it appeared that there are serious problems with implementing the regulation 258 “Energy efficiency minimum requirements” issued by the Government of the Republic on 20.12.2007 in Estonia and relying on the analysis, it can be stated that the regulation fails to put itself in practice, neither does it fulfil the posed purposes.

In order to enhance the situation, the authors of the work in question have proposed the following scenarios:

Scenario I: to impement an easier method;

Scenario II: to continue using the already existent method, required that is significantly improved;

Scenario III: to use only one specific software in order to prove the minimum requirements;

Scenario IV: to allow the use of accredited software and to impose requirements on the people performing the calculations.

Hereby it should be mentioned that the authors of the work in question would prefer the scenario III for it would provide the predictability and the comparability of the calculations. Also it is important to clarify the usage of calculationn zones in simulations.

X. CONCLUSION

Since July 2009 it is compulsory for a new or major renovation building project to meet the requirements set by Estonian Government decree nr. 258 „The Minimum Requirements for Energy Efficiency". The investigation showed that there are severe deficiencies in application of Estonian governments decree nr. 258 „The Minimum Requirements for Energy Efficiency" and set targets are not met. Only 2 project energy calculations out of 13 where done in accordance with decree nr. 258.

Reasoning behind application difficulties lie behind sophisticated level of the decree, but also problems concerning appropriate simulation software usage. There have not been institution(s) to educate enough specialists in acceptable simulation software. Furthermore, acceptable software is available in foreign language, expects high level of knowledge in the field of building energy consumption and large work experience. Often the calculation process is not easily assessable and this makes energy calculation result checks complicated. The comparing calculations of the calculation software BV2 were carried out by 9 people. The comparing calculations showed that different programs gave quite different results. In some cases the results different even in many times.

In order to enhance the situation, the authors of the work proposed four scenarios of which the scenario to use only one specific software in order to prove the minimum requirements would provide the predictability and the comparability of the calculations.

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