EUCALC

Explore sustainable European futures

Calculation tree for the Building Sector

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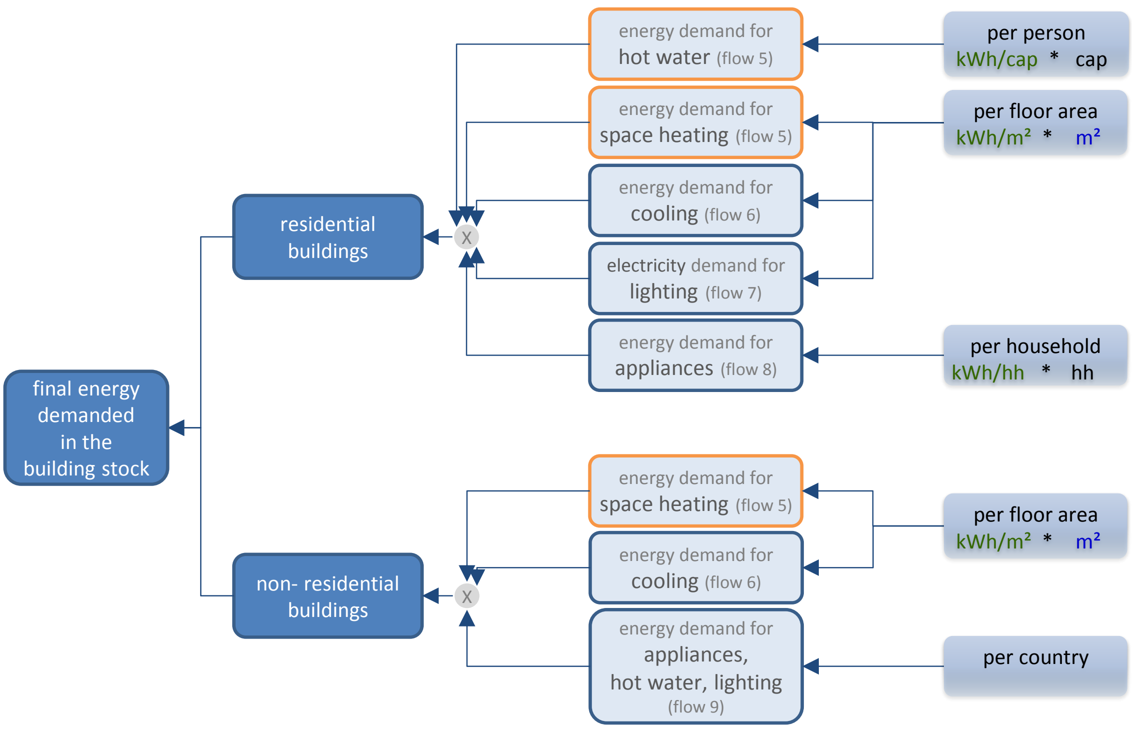
1 Introduction

The scope of the building module includes residential and service sector buildings. It seeks to calculate the final energy demand for space heating and cooling, hot water, lighting and appliances. Most uses are predominantly driven by floor area except for energy demand for hot water and appliances.

This figure below gives an overview of the building module design. It frames the scope of the model and shows its disaggregation into different calculation processes by main driver, e.g. floor area or population. On the far right, the calculation is broken down into the main drivers and the relevant specific energy factors, each with a page reference to their detailed calculation.

Building Module - Calculation for one year, per country



LEGEND

- *kWhfin* – kilowatt-hour of final energy[1]
- The circles with an X indicate an aggregation of some sort (sum, multiplication, matrix multiplication or other).

Figure 1: Building module – Calculation for one year/country

2 Residential drivers: population, households, floor area

This page contains the determination of the residential drivers: **population**, **households** and **floor area**.

As these drivers tend to differ in the density of urban regions, any parameter is given both for urban and rural areas.

Reading from the top right, the initial urban/rural population can be manipulated through the levers *population* and *urbanization* to end up with the future **population** distribution. These levers are not specific to buildings and originate in work package 1.

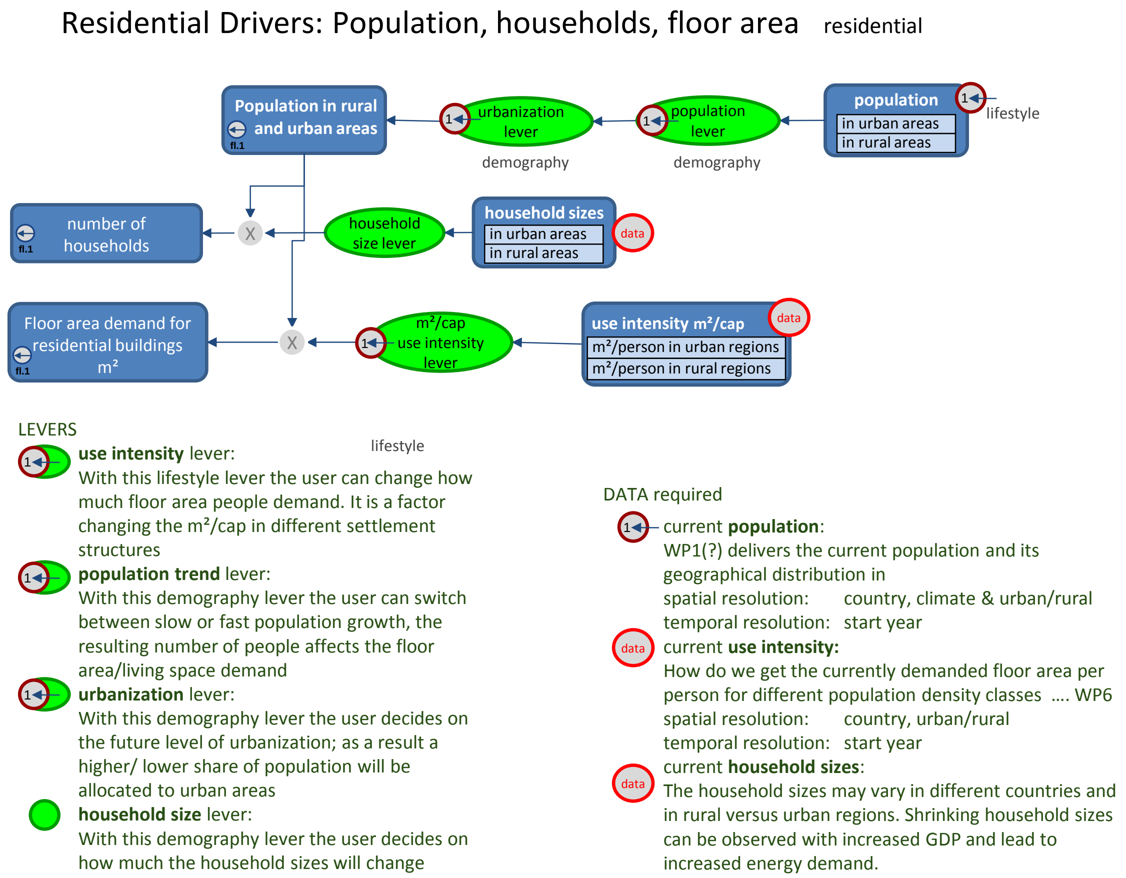


Figure 2: Residential Drivers: Population, households, floor area

LEGEND

- The green ovals indicate levers where the user may choose between four different ambition levels for climate protection/ greenhouse gas savings. The levels are yet to be determined.
- The numbered circles with an arrow going inside mark an input from another work package indicated by the number. (see input_output_flow)
- The combination of green ovals and red circles are levers that are not specific to buildings but derive from a different work package.
- The red "data" circles indicate where country specific data need to be gathered. (see data section, when competed)

Starting from the population, the **number of households** is further impacted by the *household size lever*.

To get to the **floor area,** the use intensity needs to be determined. The use area indicates how intense the living space is used, i.e. how much living space a person demands: m²/cap. This parameter needs to be determined for each country individually its urban and rural regions. The future development of this parameter may be varied by the user with the *use intensity*[1] *lever* and will determine the floor area demand for residential buildings.

[1] The use intensity lever could be seen as a part of a lifestyle definition, however as WP1 does not cover it in this detail, it might eventually come back into the building sector.

3 Heat demand side: end use energy need for space heating

Heat demand for space heating is determined on this page. This includes only the demand side[2i] and flows together with the supply side into the final energy demand calculation on page 5.

The building stock is modelled through predefined building classes (bottom right), the influence of climate and behaviour (top right) and the share of these buildings within the countries (top middle).

The building properties include geometry, u-value (heat transmission coefficient), airtightness, percentage of glass façade and their u- and g-values (solar gain parameter). As building age and size drive retrofit cost, they are included as building properties. The set of building properties is defined broadly enough to allow the representation of all the countries' building stocks. This way the only country-specific data need is the shares of each building within the respective building stock.

On the top-right, further relevant factors come in. The *climate change* scenarios from WP1 deliver outdoor temperature and insolation for the complete calculation period based on the user selection. Below, the user driven indoor temperature needs to be determined as an initial level per country and varied over time through the *heating behaviour lever*. This lever could be included in a definition of lifestyle. As the lifestyle definition of work package 1 may finally not be as detailed, this lever might come back to the building sector (lever box).

Building properties, indoor temperature and climate determine the efficiency classes. For countries with insufficiently detailed building stock data, the efficiency classes can be determined top down. Otherwise, the shares of the building classes will determine the shares of the efficiency classes. For an evolution of the building stock over time, the user may choose amongst four scenarios of increasing the *renovation rate* and the *renovation depth*, which is the ambition level for each renovation. These scenarios include different distributions of buildings across efficiency classes and the cost of the efficiency measures.

[2] The heat demand or end use heat demand includes envelope transmission and ventilation losses. Hence, it is independent from the heating system.

Heat demand side for space heating residential

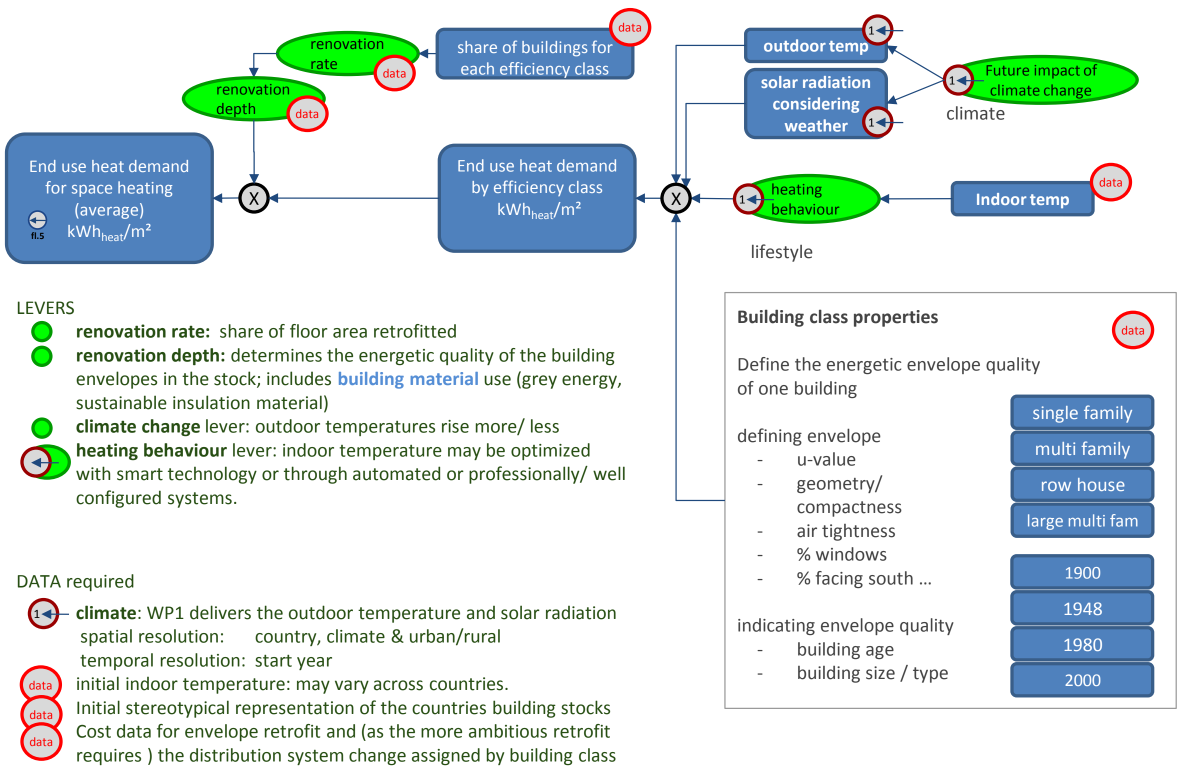


Figure 3:Heat demand side for space heating

LEGEND

- The green ovals indicate levers where the user may choose between four different ambition levels for climate protection/ greenhouse gas savings. The levels are yet to be determined.
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4 Heat demand side: end use energy need for hot water

The energy demand for hot water is dependent on the population size and thus determined per person (= per capita).

Consumption of hot water per person and per day may vary amongst countries and is potentially correlated to the GDP. The future development of this parameter may be varied by the user with the *hot water demand lever*. The hot water demand lever could be seen as a part of a lifestyle definition, however as WP1 does not cover it in this detail, it might eventually come back into (box of) the building sector.

The temperature increase for water is assumed to be 40K, which is the difference between room temperature of about 20°C and boiler sterilization temperature of about 60°C.

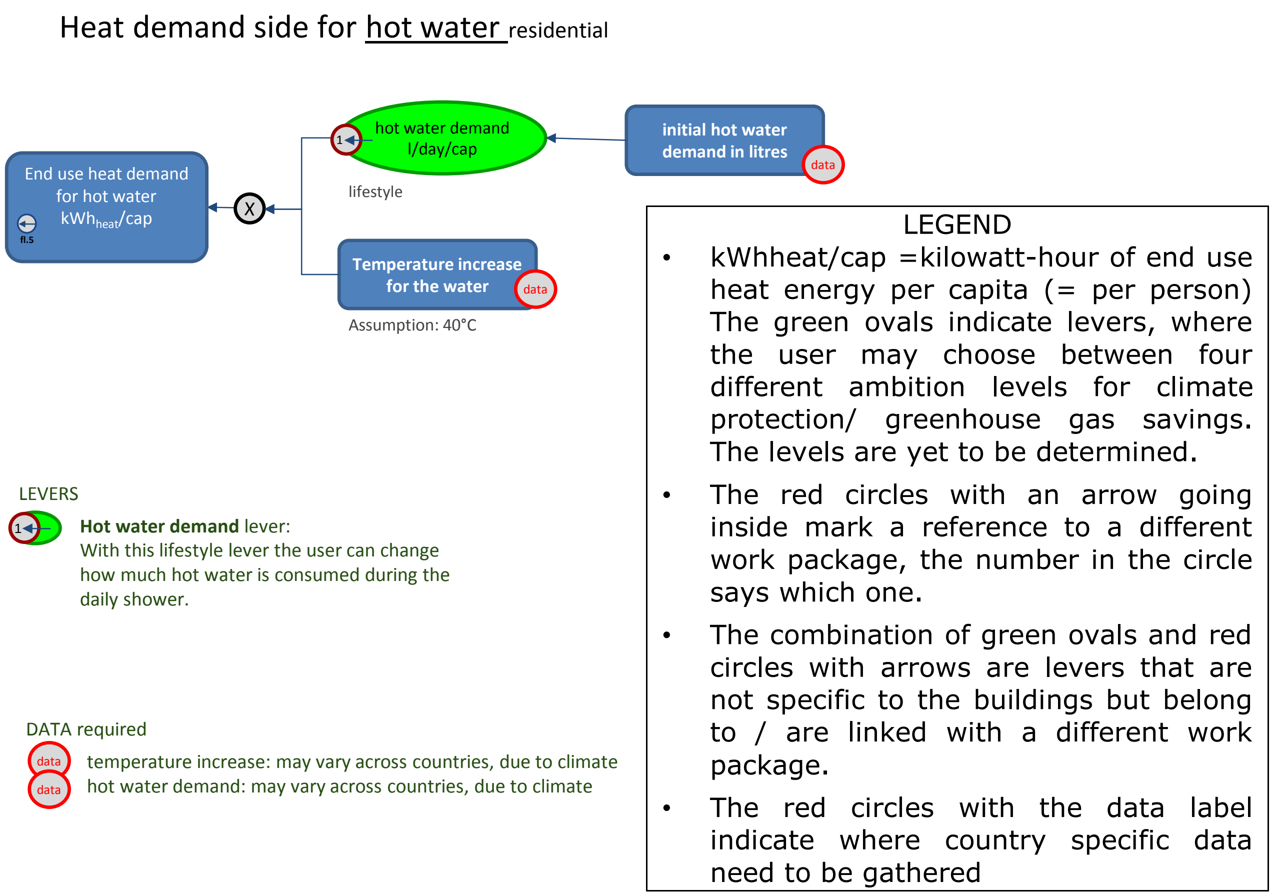


Figure 4: Heat demand side for hot water

5 Heat supply side: space heating and hot water

This page contains the heat supply side within a building and its combination with the heat demand side for space heating and hot water. The results are the final energy demand for space heating and hot water that feed back to the overview on page one.

The basis for the heat supply side calculation is the definition of the heat supply systems[3] within a matrix (bottom right). It defines all heating systems available in Europe and includes technologies, fuels and efficiency levels for distributed and district options[4]. The matrix provides the efficiency factors for each system. [5]

Starting with one matrix the calculation tree is then split into an upper branch for the district heating systems and a lower branch for distributed heating systems. The calculation processes are the same for both branches, only the levers can be varied separately.

The first calculation multiplies the efficiencies of the heating systems from the matrix with each heating system's share. Therefore, the initial share of each country needs to be known. Then, with the *technology, fuel and efficiency levers* the user sets the future share of the heat generation systems. (It is possible to split into the activity level = heat system exchange rate and into a market share of each technology.)

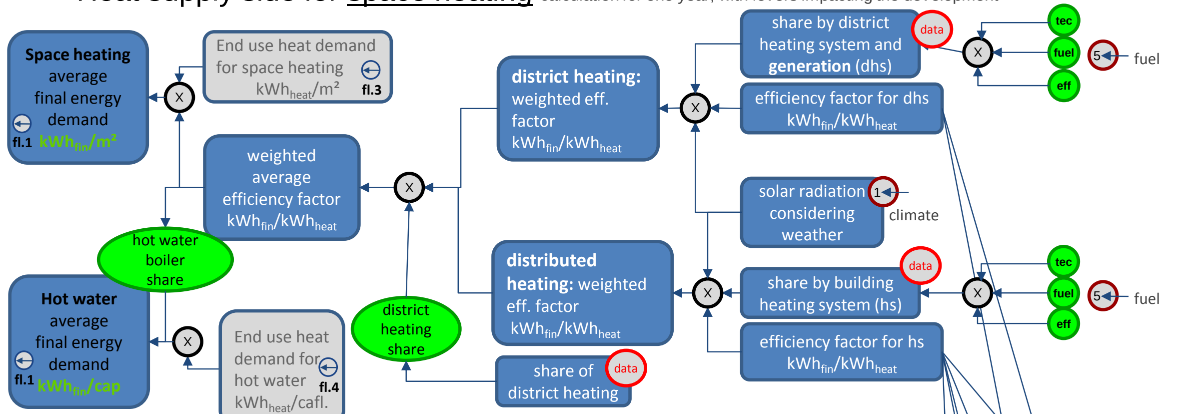
The *technology lever* sets the share of different technology, as boilers, cogeneration and heat pumps. With the *fuel lever* the user can influence the future fuel mix. However, a coherence to the overall fuel mix needs to be ensured, i.e. respecting biomass and solar potentials and alignment to electricity supply. The *efficiency lever* allows the user to drive the efficiency innovation and diffusion. As a third component in the first calculation the solar radiation determines the solar gains of a solar thermal systems. It is an input from work package 1 and included within the climate scenarios (also referred to on page 3). The result of this first calculation step is one weighted efficiency factor for district heating and one for distributed heating. This faction is the ratio of final energy demand/end use heat demand and expresses the losses during the conversion of fuels into heat energy (e.g. in exhaust gases) or the losses that occur during the internal distribution of heat within the building (heating up areas that don't need heating for comfort, for example basements and stairwells). The second calculation allocates the heat demand to district and distributed heating systems. The user may vary the future allocation of with the *district heating lever*.

[3] The system for indoor heat distribution is not considered, as it does not impact the amount of heating needed in the buildings, if you describe the building in a one zone model. The cost for distribution systems vary with a high bandwidth, therefore uncertainty is high.

[4] For the cost calculation, the matrix additionally includes the installation and the running costs for each heating system.

[5] The efficiency is given as a ratio between the final energy demand kWh_{fin} and the end use heat demand kWh_{heat}.

Heat supply side for space heating calculation for one year, with levers impacting the development



LEVERS

- District heating lever: share of district heating / uptake of potential
- **Tec**hnology share lever (separate for dh and distributed): i.e. heat pumps, cogeneration, boiler

(not?) separate for central and distributed heating

- **fuel** share lever: i.e. gas, oil, wood, solar
- **Effi**ciency share lever: different efficiencies for technology generations, i.e. low temp or condensing boilers, heat pumps and wood boilers of different generation; also district heating 1st - 4th GENERATION

mob **Fuel lever coherence**: Separate fuel mix lever for every sector/WP

- but: create coherence with overall fuel mix lever
- how: possibly achieved through a price parameter

5 **distribution system** for indoor heat is **not considered**

- radiant versus radiators, low and high temps, required for certain heating systems
- this does not impact the amount of heating needed in the buildings, it will only reduce the efficiency of the heating system;
- It is difficult to assess the cost, as there is a high bandwidth of cost depending on the individual building

Efficiency Factors (old) kWh_fin/kWh_heat	boiler	cogen	heat-pum	solar-thermal	geo-thermal
gas					
oil					
coal					
wood					
biogas					
Environmen					

Efficiency Factors (newer) kWh_fin/kWh_heat	boiler	cogen	heat-pump air	solar-thermal	geo-thermal district
gas	.85	0.95	na		
oil	.6	0.93	na		
coal	.4	na	na		
wood	.5	na	na		
water	.6	na	na		
Environmental heat			0.6	.8	.7

Matrix Set for heating systems by technology x fuel x efficiency

Figure 5: Heat supply side for space heating

LEGEND

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6 Cooling demand and supply

This page contains the cooling demand and supply for residential and non-residential buildings.

The starting point on the top right are data on the initial average cooling demand that can be observed in each country's air-conditioned buildings. For the future development, the user may vary the *cooling behaviour* as a sufficiency measure to save energy. This behaviour may also be part of a defined lifestyle in work package 1. It includes the temperature when the cooling system kicks in as well as the desired room temperature.

In the first calculation step, the cooling demand is adjusted by the development of the building envelope quality. This *envelope quality lever* has been defined already on page 3 as it also affects the end use heating demand on page 3. As a result, the end use cooling demand can now be provided as a development for the complete modelling period.

The second calculation introduces the efficiency of the air conditioning system. This efficiency is determined by country and may underpin different improvement developments that the user can select with the *AC efficiency lever*. Hence, this calculation combines cooling demand and supply to end up with the final energy demand for cooling.

The most important driver for cooling in many countries is still the saturation level, i.e. how much of the floor area is air conditioned. The initial share is determined for each country and may then be varied by the user with the *saturation lever* to determine the future development.

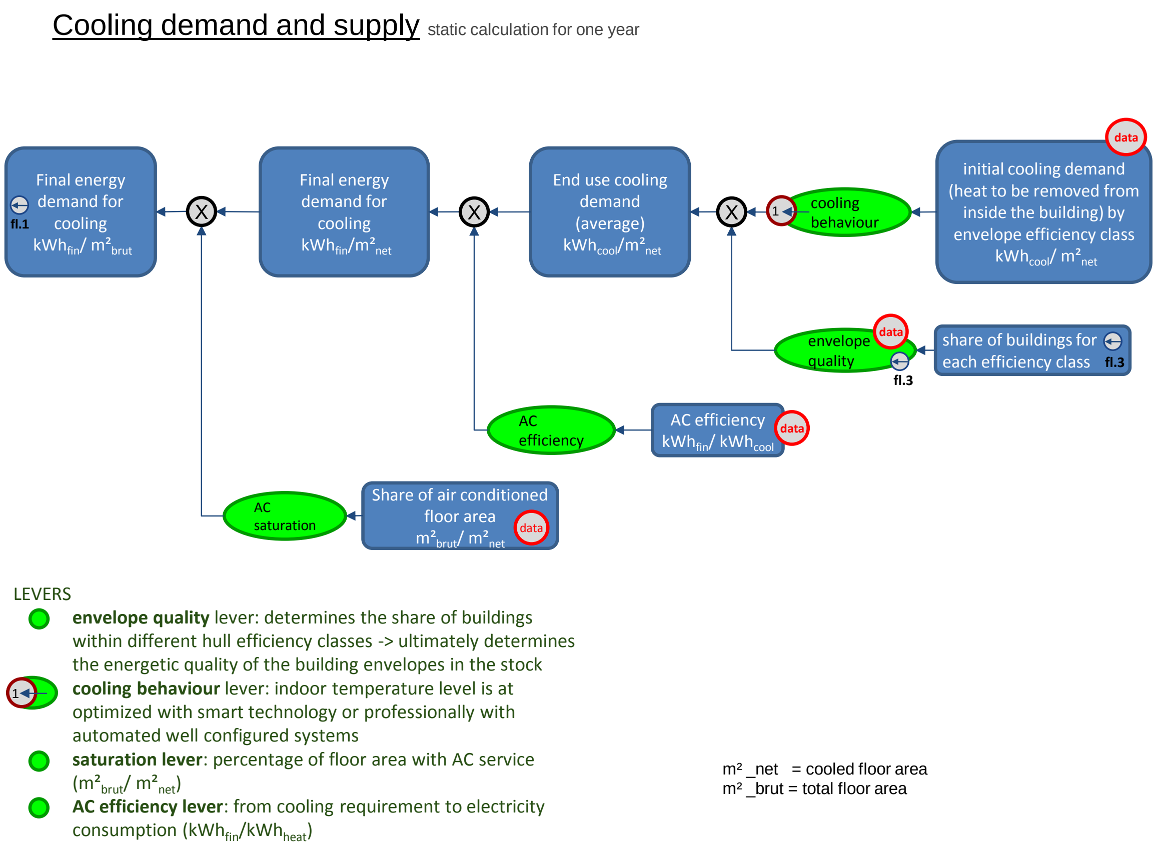

Figure 6: Cooling demand and supply

7 Electricity demand for lighting

This page contains the electricity demand for lighting in residential buildings.

The basis for the calculation is the definition of different lighting technologies and their efficiencies as indicated in the matrix on the bottom right. The initial data need from each country includes the share of these technologies used to condition the living spaces. The user may vary the market diffusion of these technologies with the *lighting efficiency lever*.

The electricity demand for lighting may now be calculated by factoring in how many hours the lighting is used.[6]

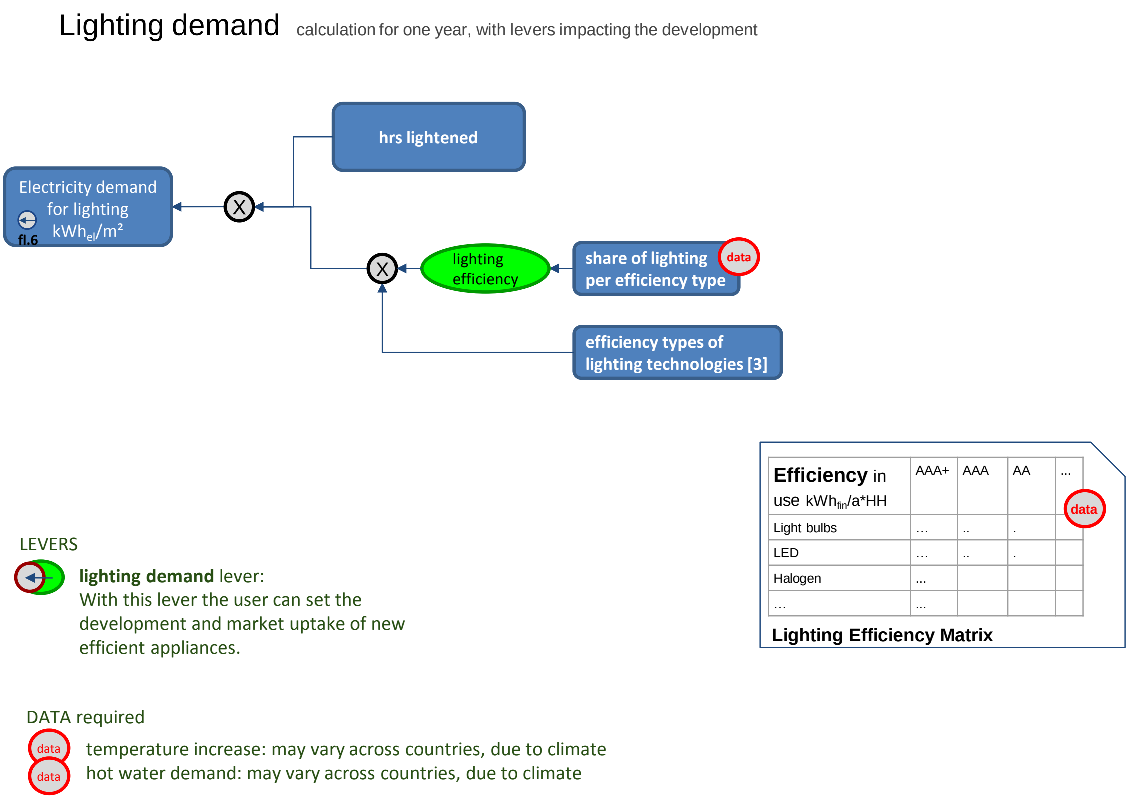

Figure 7: Lighting demand

LEGEND

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[6] *To be determined - whether to include aspects of what lighting intensity is needed and how behaviour could change lighting energy demand or the different daylight zones*

8 Energy demand for appliances

This eighth page contains the electricity demand for appliances in residential buildings.

Different appliance technologies and their efficiencies are indicated in the matrix on the bottom right. The data for the share of efficiency level needs to be collected for each country. The user may vary the market diffusion of these technologies with the *appliance efficiency lever*.

From a behavioural perspective, the occupant can contribute to energy savings with energy conscious behaviour. Therefore, the *efficient use of appliances lever* enables the user to integrate his/her own assumptions on how energy conscious people will use their appliances in the future. This lever may be part of a defined lifestyle in work package 1.

Finally, the number of appliances per household significantly impacts the respective energy demand. It needs to be determined per country initially and may then be altered by the user with the *number of appliances lever*.

Appliances use electricity and gas for cooking.

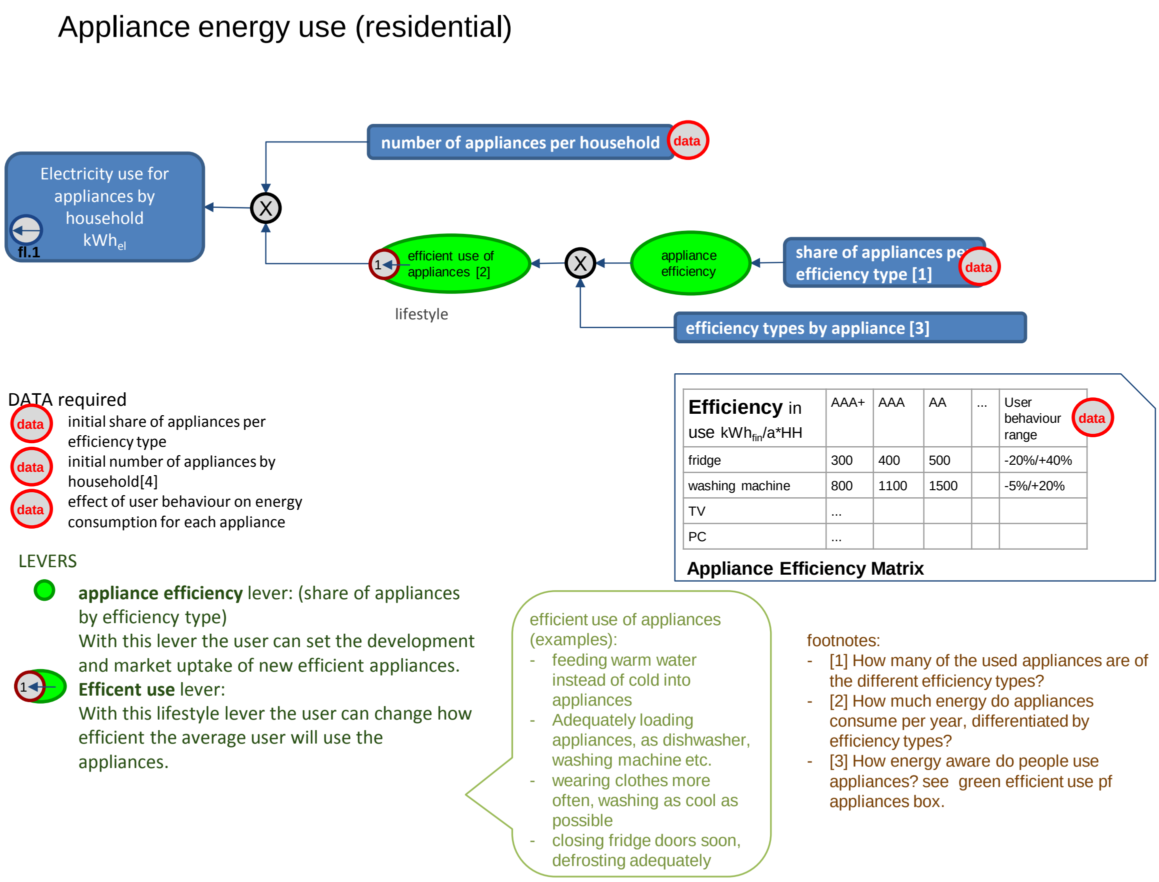

Figure 8: Appliance energy use

9 Non-residential buildings in the service sector

This ninth page describes the top down determination of energy use in non-residential buildings.

The calculation is based on the national energy balance for the service sector separated by the uses: Lighting, Appliances, Air Conditioning, ICT information and communication technology and engines/processes.

For each use the development of energy demand is separated into the *level of use* and the *efficiency of the technology*.

The model user may vary the use level, i.e. how much need for a particular end use will exist, and the efficiency of the technology fulfilling that need.

Appliance, lighting, ICT energy use (non-residential)

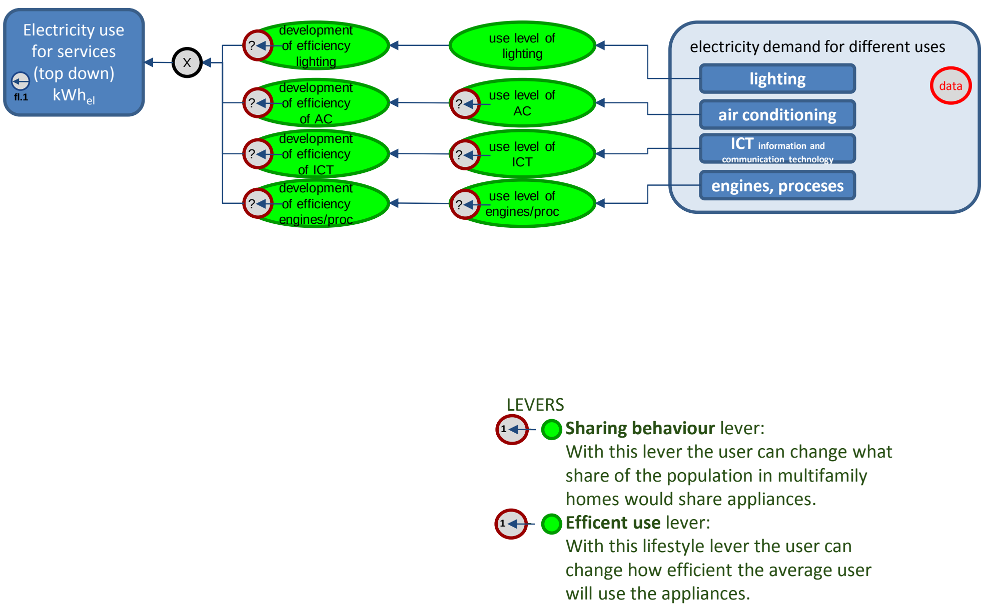

Figure 9: Appliance, lighting, ICT energy use (non-residential)

LEGEND

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[i] Background: The heat demand or end use heat demand is different from the final energy demand. The heat demand is the energy needed to keep the indoor temperature at a certain level, given the losses and gains that occur through the envelope of the building. These losses include transmission losses, heat conductivity through the envelope, and ventilation losses, heat convection. The gains include passive solar gains through windows and internal gains as waste heat from appliances and heat produced by people. The heat demand differs from the final energy demand, as it does not consider the losses that occur within the heat generation and distribution processes. Hence, the heat demand value is not solely correlated to the efficiency and type of heating system.