# Title: Residential heating sector in the Base Year (VT\_DK\_HOU\_v1\_p3 file)

# Description:

Residential buildings are aggregated according to (Legend sheet):

* Construction period - built before, after 1972 and new buildings (built after 2010).
* Region - East (DKE) and West (DKW) Denmark.
* Type of building - Single-family (old name "Detached") and Multi-family (old name (Multistorey) buildings. Single-family buildings are aggregation of farmhouses (BBR "anv" code 110), detached houses (BBR "anv" code 120), terrace houses (BBR "anv" code 130) and occupied summer houses (BBR "anv" code 510; summer houses non-occupied over whole year are not included). Multi-family buildings are aggregation of blocks of flats (BBR "anv" code 140), student residences (BBR "anv" code 150), residential institutions (BBR "anv" code 160) and other dwellings (BBR "anv" code 190).
* Location relative to existing district heating areas - Central, decentral and Individual areas. Central areas are supplied from Central DH grids (as defined in Energy Producers Count) or share a border with these areas. Decentral areas are supplied from other grids than Central (as defined in Energy Producers Count) or share a border with these areas. Individual areas do not share border with DH areas and are supplied from individual heating sources.

**Explanation of attributes in the Buildings sheet**

For the processes (column B) the commodities going into the process (column D) are heat from boilers, heat from heat exchangers (district heating) and heat savings.

The commodities going out of the processes (column E) are residential heating commodities for the specific building groups.

STOCK (columns H and I) defines the size of building stock in the Base Year.

EFF defines efficiency of building stock over the analysed period. It is an inversion of specific heating demand. The efficiency doesn't change over time because heat savings are modelled as heat generation technology.

CAP2ACT is a factor which is transforming from capacity to activity. Since both capacities and activities in this case are in Mm2 CAP2ACT is 1.

START (column G) defines the year in which the technology becomes available.

YEAR (column F) specifies the year for which the attributes in columns J--> O are specified.

AF (column M) is availability factor per time-slice. FX is short for fixed. In this case, availability factor is 1 in all time-slices.

LIFE specifies the lifetime of new capacity. Any number greater than 40 could be chosen - the only idea is that the new buildings live until the end of analysed period (2050)

Residential heating demand in the Base Year is presented in columns E and F of Dem sheet.

Residential heating demand in the future is affected by construction rates (for new buildings) and demolition rates (for existing buildings). Heat saving measures are modelled as heat generation technology and they don't reduce the heating demand.

**Explanation of attributes in the Processes sheet**

DAYNITE attribute (cells H24:H41, H47:49) means that specific commodity is tracked on the most detailed possible level (in our case this is "4 critical situations for the Danish power system": 1. high power, low demand, 2. high demand, low power, 3. High PV, low demand, 4. Remaining combinations). Other possibilities for tracking the commodities include annual, seasonal (correspond to seasons in TIMES-DK), and weekly level (correspond to Workday/Non Workday division in TIMES-DK).

FT processes (rows 42 to 51) are converting "general" commodities (such as NGA, DSL WPE,etc.) to residential commodities. The only purpose of these processes is to be able to track the use of commodities in a specific sector (in this case residential sector).

Capacity unit PJa is "PJ anually" (cells G42:G51), since both fuels coming into the processes and fuels coming out of processes are measured in PJ.

# Assumptions:

In the Danish Energy Statistics efficiency of heat pumps is assumed to be 1 because the heat from the ground is counted as an input heat.

If only electricity would be counted as input fuel to heat pump, than final energy consumption (Boilers sheet, cell T48) should be changed to 5868/2.8=2096 PJ.

"Sum of FREQUENCY" (Heat demand in new buildings sheet, cells E20:E40) represents the number of buildings. The average heated area (Heat demand in new buildings sheet, cells F20:F40) is used to calculate the heating demand in residential buildings built between Base Year and 2020 (Heat demand in new buildings sheet, cells G3:G14 and H3:H14).

Heat demand in new buildings (dwellings, hotels, collegiums) is assumed to follow building regulations:

before 2020: (52.5+1650/A) kWh/m2 per year

(source: <http://bygningsreglementet.dk/br10_03_id108/0/42>)

after 2020: 20 kWh/m2=0.072 PJ/Mm2 per year

(source: <http://bygningsreglementet.dk/br10_03_id5182/0/42>)

# References:

* CO2 emissions (Emis sheet) are taken from the Danish Energy Statistics 2013

Source: <http://www.ens.dk/sites/ens.dk/files/info/tal-kort/statistik-noegletal/aarlig-energistatistik/energistatistik2013.pdf>, page 59.

* Heat demand in new buildings:

before 2020: (52.5+1650/A) kWh/m2 per year

(source: <http://bygningsreglementet.dk/br10_03_id108/0/42>)

after 2020: 20 kWh/m2=0.072 PJ/Mm2 per year

(source: <http://bygningsreglementet.dk/br10_03_id5182/0/42>)

# Method:

Calibration of the residential heating sector is done in the Boilers sheet.

Due to small mismatches between Danish Energy Statistics and net heat demand calculated in the Heating Model, heat demand is "manually moved" from one fuel group to another (cells D34:F34, H34:K34, D37:E37, H37:J37,D38, F38, J38). As a result, boilers in the Base Year produce the same amount of heat as in the Danish Energy Statistics, i.e. TIMES-DK is calibrated with Danish Energy Statistics.

To calibrate the model with the Danish Energy Statistics these changes have been made:

\* **Detached buildings EAST**:

1.86 PJ is moved from wood (0.85 to straw, 0.01 to coal and 1 to heat pumps)

0.7 PJ from Natural gas (0.65 to Central DH and 0.05 PJ to heat pumps)

3.75\*(1-0.494)=1.9 PJ from electricity to heat pumps

\* **Multistorey buildings EAST**: No changes are made

\* **Detached buildings WEST**:

1.75 PJ is moved from wood (0.84 to straw, 0.01 PJ to coal and 0.9 PJ to heat pumps)

3.75\*0.494=1.85 PJ from electricity to heat pumps

\* **Multistorey buildings WEST**:

0.05 PJ is moved from wood to electricity

In the Heating Model summary heat demand of heat pumps and direct electric heating was matched with the Danish Energy Statistics. For that reason, they needed to be separated in cells D37:E37 and D39:E39. 0.494 is the share of electricity and heat pumps demand in detached buildings in DKW.

Equations used for calibration:

These relations are general and are valid for all process, not only in residential sector.

ACT=Activity

STOCK=Stock

CAP2ACT=Constant which is converting from capacity to activity

AF=Availability factor

CONS=Fuel consumption

EFF=Efficiency

Comparison of final energy consumption with the Danish Energy Statistics is done in table C51:N61 of Boilers sheet. Final energy consumption is calculated as:

ACT=Activity

EFF=Efficiency

FT processes are converting "general" commodities (such as NGA, DSL WPE, etc.) to residential commodities with efficiency of 1 (converting commodities in column D into commodities in column E, RES fuel sheet). The only purpose of these processes is to be able to track the use of commodities in a specific sector (in this case residential sector).

LIFE specifies the lifetime of new capacity. Any number greater than 40 could be chosen - the only idea is that the new buildings live until the end of analysed period (2050).

PASTI denotes past investments.

Heated area (Mm2) in the Base Year divided by type of buildings, position relative to existing DH areas and construction period is specified in Buildings\_stock\_eff sheet. For more details, go to Legend sheet. Energy (Heat) service demand and the energy service delivered to buildings are expressed in "Mm2 heated to 21oC" (short Mm2). Net energy (heat) demand (PJ) in the Base Year comes from the Heating Model which is calibrated with Danish Energy Statistics (Temperature-adjusted net heat demand).

Heat demand per unit of area in new buildings (efficiency of buildings) is specified in Heat demand in new buildings sheet. Heat demand per unit of area for the existing buildings can be affected by heat savings, while heat demand in new buildings remains the same during whole analysed period. Housing demand is specified in "Scen\_DEM\_FR\_APP-TRA-HOU" (Mm2\_PROJ sheet), while construction and demolition rates are specified in "Scen\_Building\_Stock\_Proj".

# Data sources:

Heated areas in the Base year (Heat demand in new buildings sheet) are copied from the Sheet "Average areas - pivot" of "Heat demand" tool. These values originate from DTU energy atlas based on the BBR dataset.

* CO2 emissions (Emis sheet) are taken from the Danish Energy Statistics 2013

Source: <http://www.ens.dk/sites/ens.dk/files/info/tal-kort/statistik-noegletal/aarlig-energistatistik/energistatistik2013.pdf>, page 59.

* Heat demand in new buildings:

before 2020: (52.5+1650/A) kWh/m2 per year

(source: <http://bygningsreglementet.dk/br10_03_id108/0/42>)

after 2020: 20 kWh/m2=0.072 PJ/Mm2 per year

(source: <http://bygningsreglementet.dk/br10_03_id5182/0/42>)