01-00: Single-family houses and domestic energy…

Single-family houses will typically be connected to the electricity grid for food preparation and preservation and also for home electronics. The use of biofuel in single houses is then to cover the need for comfort heating and for tap water.

The characteristic for single houses is that the variations in energy need may be very different from hour to hour. For example will the fact that one person in the household takes a shower suddenly demand a rise in heat supply to the hot water system and if windows are opened for intensive ventilation the demand for heating suddenly increases radically. Also the opposite is true: A party with 20 participants will suddenly increase the heat supply to the house with about 2-3 kW (*one person releases approximately 100 W only in the form of body heat and if they are dancing the heat release increases*) and there might suddenly be a demand for cooling…

In case cooling is needed in a single-family house, this is usually arranged by installing separate AC-units in the rooms where the need is most pronounced, or to have a mobile AC-unit that is moved to the room where it is needed. For single houses only compressor cooling machines are applicable.

Hence, the stationary energy system in single houses can have only two roles, namely to provide heat and to provide tap water. Houses without central heating systems are not considered in this material.

Two main alternatives – air-borne or water-borne
Central heating in single-family houses can be water-borne – which is preferred in case of biofuel – or it may be air-borne. In case of water-borne heating, the production of tap water is normally integrated in the same boiler but – of course – with a separate heat exchanger coil. In case of air-borne heating, the production of tap water becomes a completely separate system.

With water-borne systems, the boiler may be complemented with an accumulator tank to even out thermal load. The accumulator tank shall be large enough to cover the average heat demand of the house, tap water and heat combined, during 24 hours with a temperature drop of about 20 ºC. With an accumulator tank integrated in the system it is simple to integrate solar heating with the system by a separate heat exchanger coil in the accumulator. There are also some domestic boilers that have extra large water volumes – though not as large as can be obtained by a separate accumulator – and also comprising solar heating connections.

Since the water volume in the boiler itself – or in the combined boiler and accumulator – is significant, a water-borne system will provide a thermal inertia that simplifies the control of the system. A sudden increase of the hot water demand, for example, can then be supplied from the stored energy in the system so that the demand can be met while the heat input (*for example a pellet burner*) might need some time to get started. The larger the thermal inertia, the longer start-up times may be accepted.

With air-borne heating systems, the thermal inertia is close to zero and the heating system must respond almost instantaneously. For this kind of systems, air-heating, pellet fired stoves are available on the market. For the supply of hot water, though, separate water heating devices become necessary. The water heaters must – in combination with air-borne heating – have extremely short response times and gas heaters or electric heaters would be preferred.

Different time constants…
With a water-borne system without accumulator, the time constant for the water to cool down significantly is measured in single hours while, if an accumulator tank is included, the tank should be dimensioned so that the time constant becomes about 24 hours under normal circumstances.

Hence, the water borne systems without accumulator can be combined only with primary energy supply systems having shorter time constants from "off" to full power less than approximately one hour. For firewood, the time from "off" to full power is anything from a few minutes to half an hour depending on the skill of the operator. For modern, automatic pellet burners it is a few minutes. For gas and electricity it is seconds.

For air-borne heating systems, the time constant is significantly less than one hour and any type of log-firing is effectively out of question while pellets, gas and electricity are all viable alternatives.

For on-line water heating, water heaters to be combined with air-borne heating systems, the required time constant is less than a minute and only gas and electricity are alternatives.

Thus, this again points out the importance to install water-borne central heating in houses intended for biofuel heating.

The control system
The energy system in single-family houses can not take very high investments and is thus controlled using a simple on-off system. With water-borne systems the control parameter is normally the water temperature in the boiler or the accumulator while air-borne systems, especially if the system is distributed with several stoves and heat sources, may have thermostats in several rooms. With water-borne systems the temperatures in individual rooms are set by aid of radiator thermostats.

The control system may also include a timer control so that the temperature set points are different between night and day, thus providing a lower night temperature. The theoretical basis for such a control is that a lower indoor temperature overnight will contribute to a lower mean temperature: 20 ºC during 18 hours plus 16 ºC during 6 hours yields a temperature average of 19 ºC per 24 hours period. Since the heat losses from a building are roughly proportional to the temperature difference between the indoor temperature and the outdoor temperature, then such a temperature decrease might lower the total energy losses from the house by 10 % in case the outdoor temperature is 10 ºC. In this example, the temperature difference was 10 ºC as the indoor temperature was 20 all around the clock while the difference is only 9 ºC with the decrease in temperature overnight. Since 9 degrees temperature difference is 90 % of 10 degrees temperature difference the heat loss – and hence the need for heat supply – will be reduced to 90 % giving a saving of 10 %.

The actual effect of a low temperature set point overnight depends strongly on the total thermal inertia of the building; the larger the thermal inertia – the lower the effect. Hence will this be an alternative in light, wood structure and wood frame, buildings, while heavy stone buildings will show no or only marginal energy savings by this method. The effect of low night temperature set points on energy saving is enhanced by the use of air-borne heating systems.

Limits to the combustion process
Any fireplace is designed to work best with a specific fuel at a specific firing rate (i.e. thermal output). Good combustion equipment – fed with the correct fuel at the correct rate – will provide a complete burnout of the fuel in combination with minimal amounts of air pollutants. This is especially important in case of individual house heating, be the houses large or small, with individual boilers. A cluster of buildings – all emitting for example high concentrations of soot or heavy hydrocarbons – may well cause the outdoor air quality to become a local health hazard. Also may nitrogen oxides be formed, and they, too, represent a source of air pollution.

As already pointed out in chapter 00-01, the combustion process is an intricate combination of aerodynamics, heat- and mass-transfer, and chemistry.

Not going into any detail, it might be clear that a small thermal output requires only a small fireplace and it might also be clear that if a single fuel particle occupies a large fraction of the volume in the fireplace, the combustion results will to a great extent be determined by the combustion of that single particle. Fundamentally, this is the reason that log-firing in single family houses may result in very high emissions of unburned hydrocarbons: The single fuel particles will have variable properties and the single “particle” will occupy a significant amount of the fireplace volume. Even the most advanced boilers will hence, ultimately, be subject to the properties of the wood-logs and the demand for a dry and uniform fuel will fall heavy on the user.

With wood pellets, the particles are uniform in shape and quality, they are comparatively small and the environmental performance of pellet combustion for single-family house eating is always far superior to that of common wood-log firing.

Relevant standards
A central heating system may represent a significant investment for the single household and it is important that the equipment bought fulfils all reasonable quality criteria. The European federal standard EN 303-5 (see the FOREST StandardGuide) covers testing procedures and marking of boilers for this sector. Furthermore, EN 15316-4-7 covers the dimensioning methods for single-house heating systems.