Biomass Heating Systems

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Keywords: Biomass and bioenergy. Sustainable biomass products. Socio-economic aspects of bioenergy systems. Biomass technologies. Biomass heating systems for housing. Solar-supported biomass district heating. New generation of pellets-boilers. Biomass-combined heat recovery unit.

1. Background

Biomass is all plant and animal matter on the Earth's surface. Biomass is a very broad term which is used to describe material of recent biological origin that can used either as a source of energy or for its chemical components. As such, it includes trees, crops, algae and other plants, as well as agricultural and forest residues. It also includes many materials that are considered as wastes by our society including food and drink manufacturing effluents, sludge's, manures, industrial (organic) by-products and the organic fraction of household wastes. Biomass can be further divided into more specific terminology, with different terms of different end uses: heating, power generation (electricity) or transportation.

The term "*bioenergy*" is used for biomass energy systems that produce heat and / or electricity and "bio fuels" for liquid fuels for transportation. Harvesting biomass such as crops, trees or dung and using it to generate energy such as heat, electricity or motion, is bioenergy. Bioenergy can also be used for cooling using absorption chillers that work on the same principle as refrigerators.

Using biomass to generate energy presents many new opportunities for communities in all parts of the world to improve quality of life. At the same time "bioenergy" contributes to regional and national prosperity and helps in the fight against global climate change.

2. Bioenergy products

Bioenergy products are offered in form of fire wood, bark and wood chips from the forests and as remnants of the wood processing industry. When they exist locally, and grow again they do not pollute the environment with greenhouse-relevant carbon dioxide emissions when used; Figure 1a and b.

The main biomass resources include the following: short rotation forestry (willow, poplar, eucalyptus, e.g.), wood wastes (forest residues, sawmill and construction/industrial residues, etc.), sugar crops (sugar beet, sweet sorghum), starch crops (maize, wheat), herbaceous lignocellulosic crops (miscanthus), oil crops (rapeseed, sunflower), agricultural wastes (straw, slurry, etc.), municipal solid waste and refuse, and industrial wastes (e.g. residues from the feed industry). At present, biomass in the form of wood wastes, agricultural wastes, municipal or industrial wastes, are the major biomass sources and are, arguably, the priority fuels for energy production. In the long term, energy crops will be an important biomass fuel.

"*Sustained*" produced bioenergy is an effective and perpetual option for reducing greenhouse gas emissions and resolves critical issues of sink options.

3. Biomass – a renewable energy source

In many ways biomass can be considered as a form of stored solar energy. The energy of the sun is "captured" through the process of photosynthesis in growing plants; Figure 2a to c.

Using biomass as a fuel means that carbon dioxide (CO_2) which was absorbed from the air while the plant was growing, is released back into the air when the fuel is burned. The system is said to be "*carbon neutral*". Providing the balance is maintained between the plant growth and biomass use, the system is sustainable and helps combat climate change. On the other hand, deforestation can not be considered "carbon neutral"; Figure 3. For managing eco-systems for bioenergy production good and environmental sensible forest management is essential.

There is a vital difference between energy production from fossil fuels and from biomass. Burning fossil fuels releases CO_2, that has been locked up for millions of years in the ground and will require many more millions of years to return back to the ground. By contrast, burning biomass simply returns to the atmosphere the CO_2 that was absorbed as the plant grew over a relatively short period of time and there is no net release of CO_2 if the cycle of growth and *harvest is sustained*; Figure 4.

The forest carbon cycle

A forest stand in a conventional forestry system passes through several stages, beginning with regeneration or stand establishment, continuing through the sapling stage or rapid height growth, the intermediate stage of steady growth in diameter and height, finally reaching maturity and harvest and returning to the regeneration phase. There are many variations on the basic cycle. The full cycle or rotation could last from 10 years to 200 or more, though it is typically between 30 and 80 years.

The use of bioenergy on a sustainable basis will provide a substantial contribution to meeting future energy demands.

Due to the nature of its landscape, Biomass is a major energy source for some European countries: Austria, Switzerland, Sweden, Finland, Denmark. In these countries, Biomass is considered a promising energy resource because it can be easily converted to a wide range of products including gaseous and liquid fuels, electricity, chemicals and process heat. Biomass has an economically limited collection radius where it can be used. Therefore the commercial market penetration that has occurred varies from location.

4. Socio-economic aspects of bioenergy systems

Community bioenergy projects offer the opportunity of using local resources to support the local economy. As such, they could form a part of almost any generation of diversification activity in a given locality, adding local value.

Local communities can benefit from biomass for energy use in many different ways. The most obvious is new jobs created in local businesses. Environmentally, biomass-based energy supply options can create a more varied and accessible rural hinterland for communities to enjoy. Small scale community heat production from centralised community bioenergy facilities is an important instrument for regional development. An additional benefit is the reduction of a country's dependency on imported energy.

5. Biomass technologies

The present principal market targets of the bioenergy community are in the area of

- residential heating,
- co-firing biofuels with coal,
- gasification for electricity and
- transportation.

Technologies for biomass utilisation are:

- heat and power production,
- combustion and gasification of solid biofuels,
- stoves and boilers for steam power systems, gas turbines/engines, Stirling engineLiquid fuel production "*Biodiesel*" from oil bearing plants and food residues
- ethanol from starch and sugar bearing crops and lignocellulosic,
- bio-oil from flash pyrolysis of lignocellulosic.

Along with the use of forestry products for bioenergy, agricultural biomass production has also received significant attention. Biogas has also received a lot of attention and the number of biogas plants is increasing both in agriculture and in waste management.

Biomass is the oldest fuel known to man. It is also one of the most versatile and in modern-day systems, a clean and efficient way to produce heat and electricity. Most commonly, wood is chopped into chunks or chipped for ease of handling or even pelletised so that it can be pumped.

Bioenergy for residential heating is already cost competitive in certain regions where waste streams, residue or dedicated resources provide free or inexpensive inputs.

6. Biomass heating systems for housing

Fire wood boilers have a long tradition in many European countries. In the past, the efficiency of existing fire wood boilers was poor and therefore are the impacts to the environment high.

The revival of biomass use was actively supported by R&D efforts to improve wood combustion technologies; Figure 5. The result of these efforts was a remarkable development which provided the basis for the growth of the market for wood boilers for domestic heating, industrial process heat applications and district heating. Converging forces for the market deployment of high-efficient and environment-friendly biomass-boilers are new standards in many countries concerning efficiency and emissions of heating systems.

The operating comfort of biomass boilers could be improved by features of full automatic operation and a similar comfort as oil or gas fired boilers: *woodchips*- and *pellets-boilers*; Figure 6 and Figure 7a and b.

In low-energy housing biomass heating systems have to meet the requirements of efficient environmentally acceptable heating systems: High automation and operation safety, low noise and dust emissions, optimisation of efficiency and emissions to be achieved under operating conditions when the heat demand of the building is 30% below the peak heat demand, taking into account “stop and go” operation mode. Therefore, the ratio of burning period to interval period biomass heating systems has to be minimised by a buffer store, and the hot water preparation during the summer period has to be covered by other sustainable energy sources, e.g. solar energy.

Biomass is an attractive renewable energy source for space heating of buildings as well as auxiliary energy source for a solar combisystem. With a *combined solar-biomass heating system* the contribution to the heat demand of a building (space heat and hot water) is covered to 100% by renewable energy sources; Figure 8a to c.

Within series production of small biomass heating systems, especially pellets-boiler cost-effective products are offered on the market nowadays. Pellets offer the possibility to use wood as a fuel without any reduction of convenience in comparison to heating oil or natural gas. Pellets are transported in a tank lorry and pumped dust-free into a storage; Figure 9a and b. From there, they are fed to automatically working pellets boilers.

Today, pellets boilers are fully developed in a number of options and environment-friendly in every respect. Operating data of pellets-boilers are documented in Table 1. Heating with pellets is economical at the current (December 2003) price level of heating oil and natural gas. New on the market is a storage-integrated pellets-burner; Figure 10a to c. This compact system supports both high efficient use of pellets and cost-effective installation.

Pellets-boilers can be combined also with heat recovery systems. Nowadays, a compact system is offered on the market; Figure 11

7**6.** **Solar-supported biomass district heating**

The heat supply of smaller communities can be changed to local renewable energy sources with the setting up of small district heating plants on the basis of locally available biomass within a short period, without substantial modifications of the individual heating systems in the building’s. Communal small-scale biomass district heating plants cause problems when used all year because through the low heat consumption outside the heating season the biomass boiler cannot operate efficiently and thus lacks the attractiveness of its use throughout the year for the operating company. The boilers are generally largely oversized for their use outside the heating period and therefore the boilers are operated with a very low load and with a frequent On/Off-operation, respectively. With that, firstly great losses through heating up and later cooling off and secondly poor efficiency have to be accepted. Operating in this way also causes higher emissions which promote pollution, especially the linkage of ground level ozone during the summer months.

With solar-supported biomass district heating plants it shall be achieved that heat outside the heating period can be produced to a large extent through the solar plant, and therefore the district heat supply is more attractive for the potential consumer through its all year operation. Also the low load operation of the biomass boiler is reduced and thus the ensuing emissions. Checks of the boiler will be possible without an interruption of its operation and thus prevent an energy supply bottleneck which is linked with it. Furthermore the efficiency of biomass district heating plants is improved.

The installation of solar supported district heating plants was facilitated through the development of large-scale collectors with up to 15 m² absorber area. With this development not only the costs for the collectors and for the installation were decisively reduced but also the problems arising when connecting the pipes by means of prefabricated collector modules were remarkably reduced; Figure 12.

The hydraulic schemata if solar supported district heating plants show Figure 13a and 13b. For district heating plants the hydraulic concept is of high importance. In principle 4-pipe-networks and 2-pipe-networks are used. The evaluation based on experimental data shows clearly that 2-pipe-nets have obvious advantages over 4-pipe-nets when it comes to the plant efficiency and utilisation of the solar system. 2-pipe-nets reveal the lowest need for auxiliary energy in all building geometries and energy densities; Figure 13b. The advantages of 2-pipe-nets concerning the need for auxiliary energy are greater in less compact buildings (low energy densities) than in compact buildings (multiple-storey buildings, high energy densities). On the one hand the 2-pipe-nets reduce the distribution losses and on the other hand the low temperatures from the energy distribution network offer optimum starting conditions for the thermal solar plant which translates into higher solar yields.

Experimental data of a combined solar-biomass district heating plant in Austria (Figure 14a and Fig 14b) are illustrated in Figure 15a and 15b. In order to cover the heat demand for hot water outside the heating season mainly by solar collectors a thermal storage with a capacity for 3 to 5 days was installed. Even if the solar share for space heating and hot water preparation is only about 14% of the annual average, but the solar share for hot water preparation outside the heating season is more than 80%; Figure 15b. The relatively high losses in small-district heating systems - mainly through the pipes in summer is caused by the low heat consumption during the summer months.

To ensure the operation of a combined solar-biomass district heating plant which is as efficient and thus as economic as possible high requirements are made on planning, installation and operation. The following parameter, based on the first operation data, are important for the performance of a combined solar-biomass district heating plants.

The efficiency of biomass district heating plants is essentially determined by

- the number of users: density of supply
- the lowest possible heat loss in the heat distribution:
  improved heat insulation of the pipes,

Design principles for solar supported biomass district heating systems are illustrated in Figure 16 a and 16b.

The design of the heat distribution net should take place on an as low as possible return temperature. In the case when lowering the return temperature from 70°C to 65°C the efficiency is improved by 7.4% and when lowered to 60°C by 14.8%.

A suitable recharging strategy of the boiler has to be planned to be able to use the collector heat as efficiently as possible. It should be the aim to feed the solar heat into the buffer storage at its best position.

To minimise the system heat losses, an appropriate insulation for heat storage and pipes has to be considered. Even if the buffer storage is only a short-term storage for several days heat insulation should be taken into account. For example, the heat losses with a heat insulation of 20 cm are reduced to about 53% in comparison to a heat insulation of 10 cm. If the heat insulation is 50 cm then the heat losses in the buffer storage are only 23% of a storage with 10 cm insulation. The heat insulation of pipes in the collector circuit should be at least 5 cm.

Regarding the emission savings potential there is a high dependency on the respective boiler dimensioning, due to the increased emission output of boilers in cycling operation.

Operation monitoring of a complex heat producing plant is essential for an efficient operation and require all the essential operating data collected continually, filed and evaluated. In this way it is possible to locate breakdowns of technical equipment soon. Good systems for operation monitoring make it possible to intervene directly in the operation. Measured data like temperature, operation hours of pumps, as well as the heat flow are the basis for the regulation. Such measurements allow a good check of the quality of the design, installation and operation. When measuring the temperature care has to be taken that an accuracy as high as possible is reached. Since the regulation works with a difference in temperatures of about 5°C, it is necessary that measuring mistakes remain very much below this figure. Special attention has to be paid to the correct feeding of the temperature sensors. Temperature sensors which measure incorrectly or are in the wrong position often result an inefficient operation of the plant.

Table 1
Operating data of 15 Pellets-boiler from Austrian producers
Tests : Bundesanstalt für Landtechnik, Wieselburg/Austria, 2002

Characteristically data	Load	Unit	Best	Worst	Average	Maximal allowed (2)
CO	100%	mg/MJ	9	218	**72**	500
		mg/Nm³	14	334	**110**	
	30%	mg/MJ	65	557	**204**	750
		mg/Nm³	99	857	**312**	
C_xHy	100%	mg/MJ	1	3	**1,5**	40
		mg/Nm³	1	4	**2,1**	
	30%	mg/MJ	1	11	**3,8**	
		mg/Nm³	1	17	**5,2**	
O_2	100%	%	5,1	9,4	**7,3**	
	30%	%	10,3	15,1	**12,0**	
Efficiency	100%	%	92,3	86,7	**89,5**	
	30%	%	92,8	83,4	**87,6**	
NO_x	100%	mg/MJ	52	101	**76**	150
		mg/Nm³	76	137	**105**	
Dust	100%	mg/MJ	5	22	**10,5**	60
		mg/Nm³	8	34	**16,3**	
Electricity demand (1)	100%	%	0,2	1,4	**0,7**	
Radiate emissions	100%	%	0,7	4,2	**1,7**	

1) Related to design load, 2) Legal code in Styria/Austria

More information:

Gerhard Faninger: "Combined Solar-Biomass District Heating in Austria"
Solar Energy Vol. 69, No. 6, pp. 425 - 435, 2000.

www.iea-bioenergy-task29.hr
www.iea-bioenergy.com
www.solarfocus.at
Kalkgruber Solar- und Umwelttechnik GmbH, Werkstraß1 1,A-4551 St. Ulrich/Steyr

Fig. 1a: Biomass from forests and wood industry

Fig. 1b: Biomass products: fire wood, wood chips and pellets

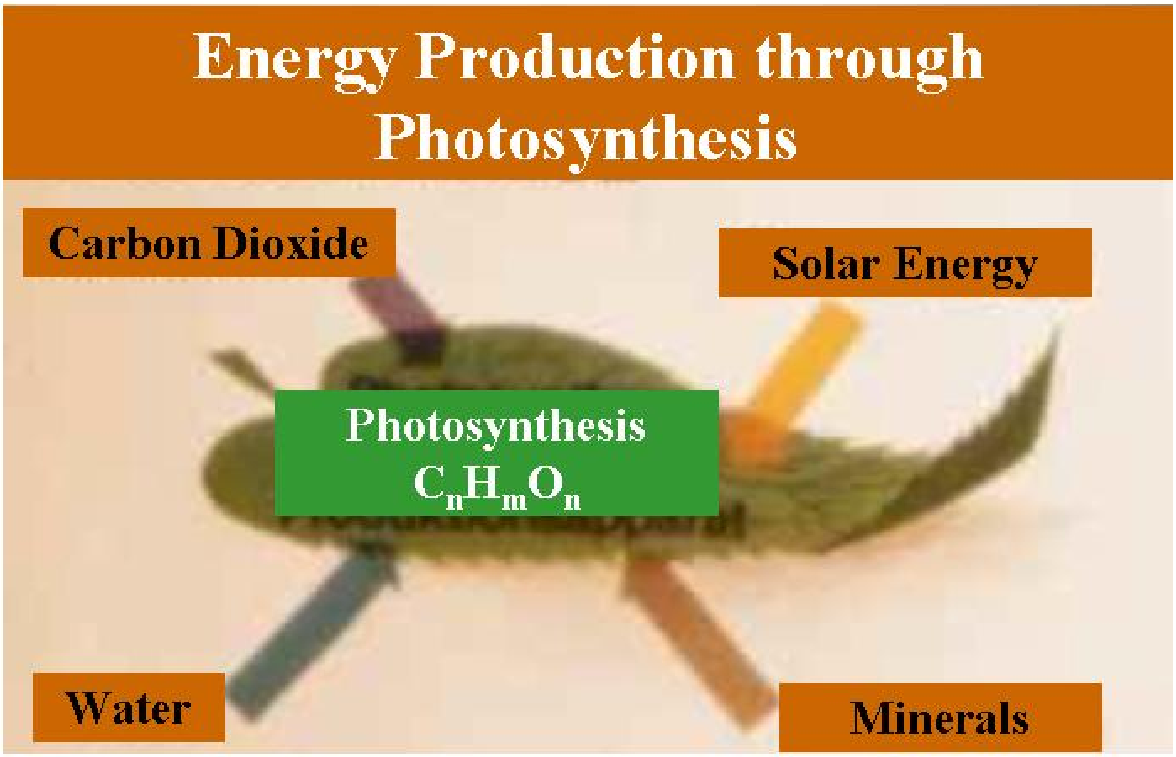


Fig. 2a: The principle of photosynthese

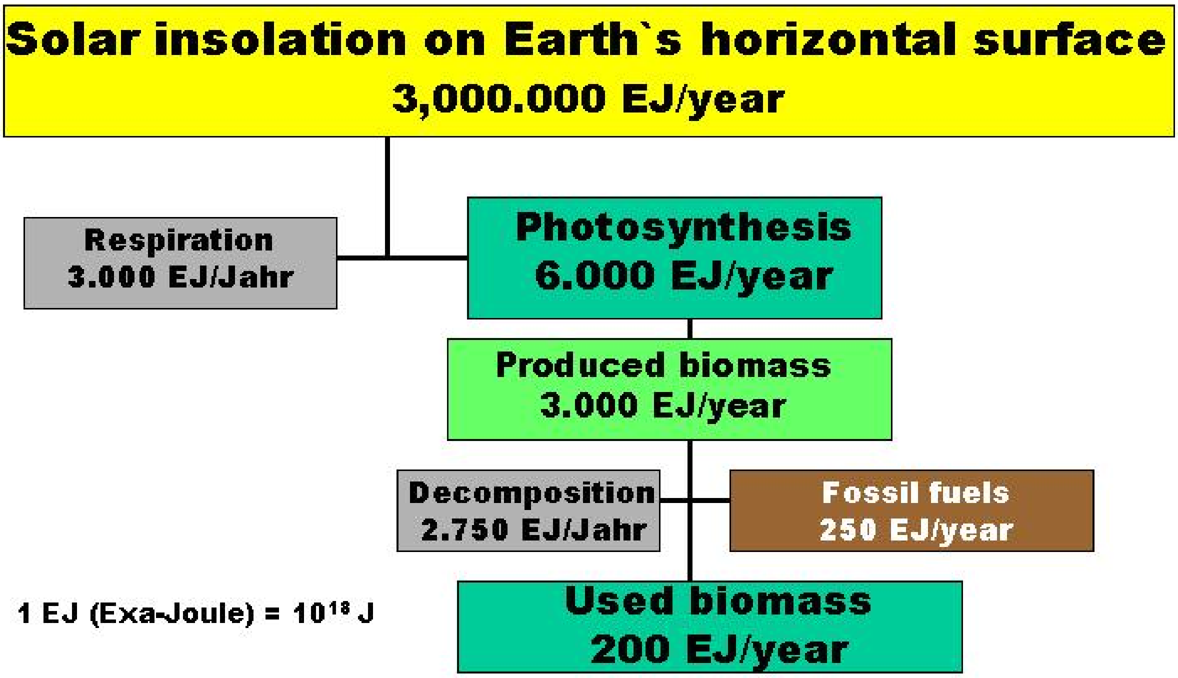


Fig. 2b: The global biomass cycle

Chemical reactions for production and photosynthetic fixed carbon dioxide

Carbon dioxide emission of biomass

Micro-biological decomposition and burning of biomass

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$$

Photosynthetic fixed carbon dioxide

Growth of biomass

$$6\ H_2O + 6\ CO_2 \rightarrow C_6H_{12}O_6 + 6\ O_2$$

Fig. 2c: The carbon dioxide cycle

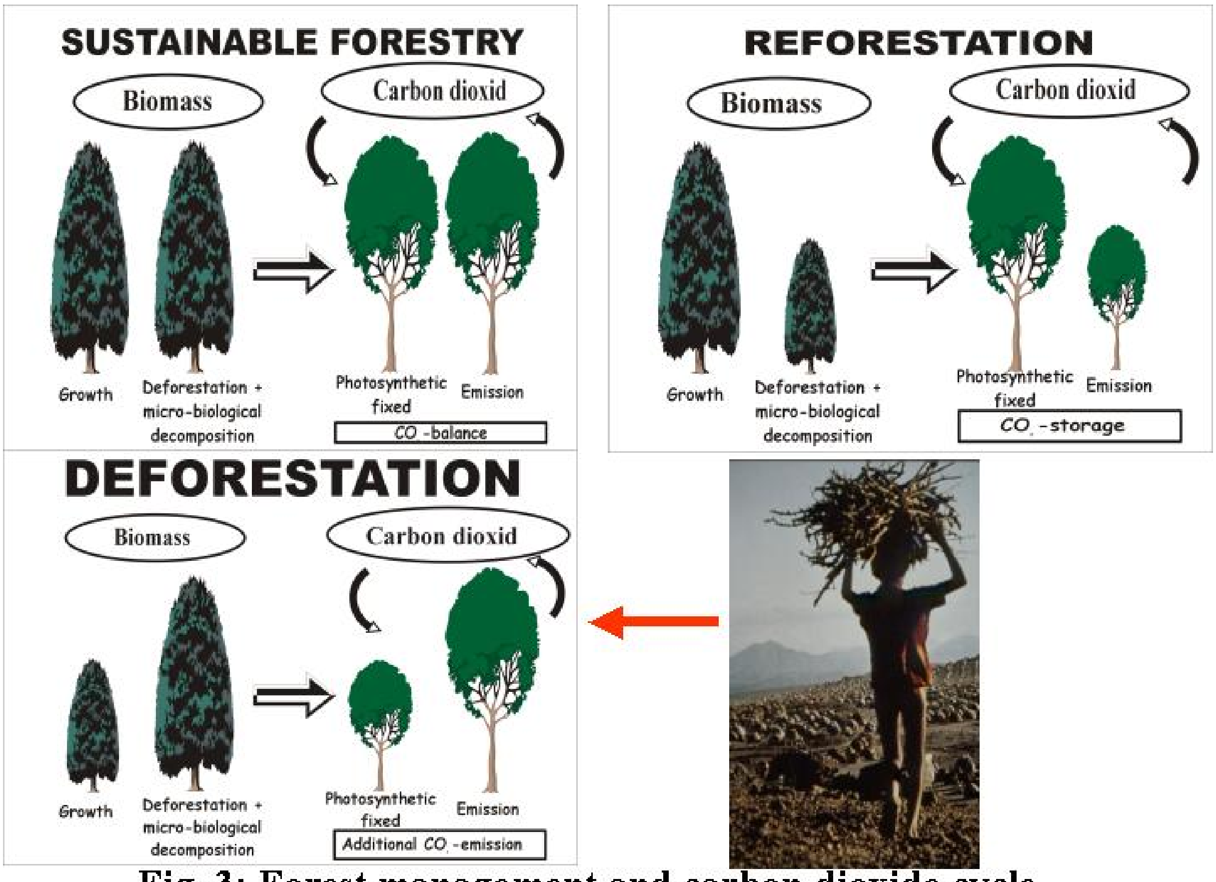


Fig. 3: Forest management and carbon dioxide cycle

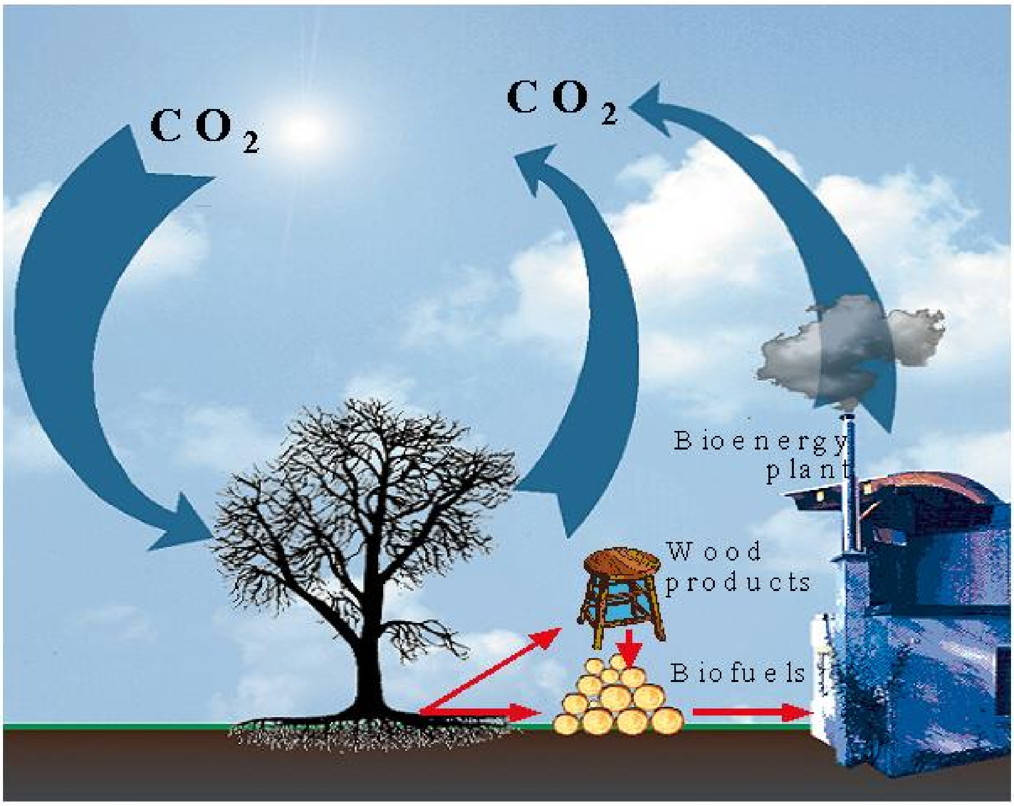


Fig. 4: Biomass use and carbon dioxide cycle

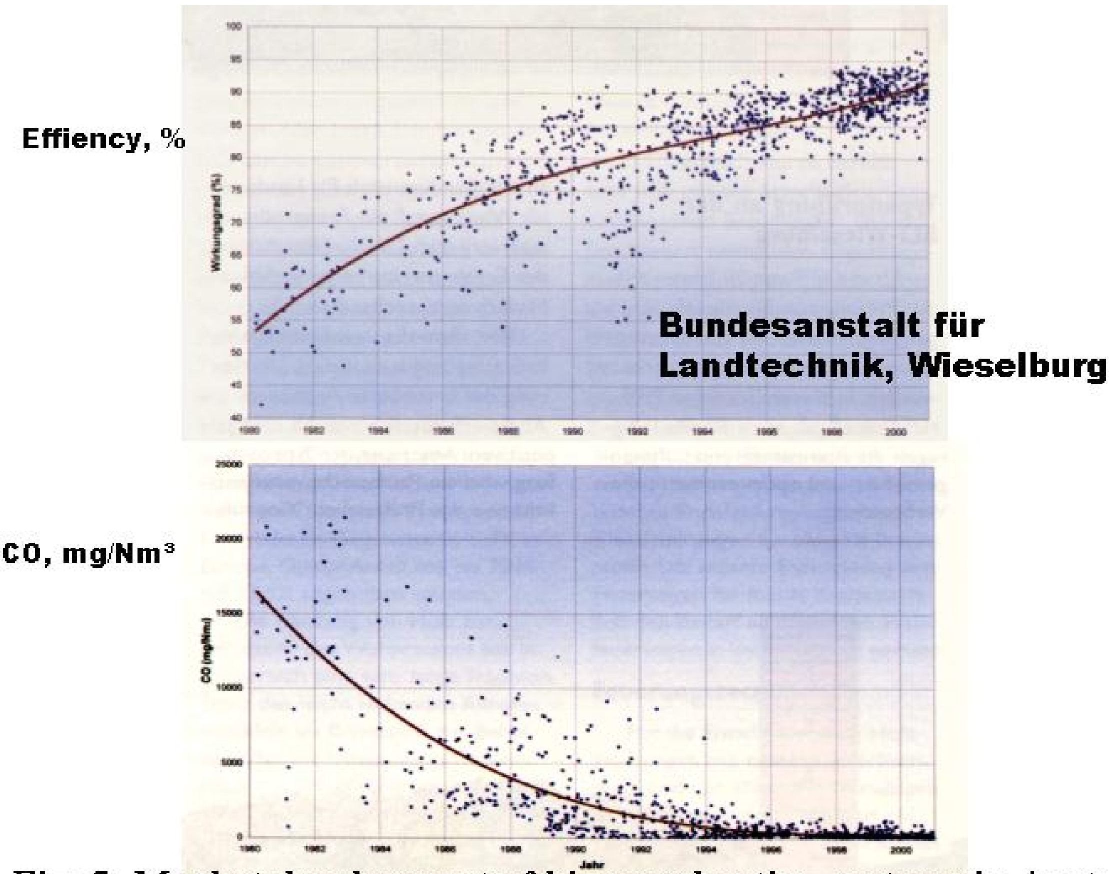


Fig. 5: Market development of biomass heating systems in Austria

Fig. 6: Biomass heating for housing: stoves and boilers

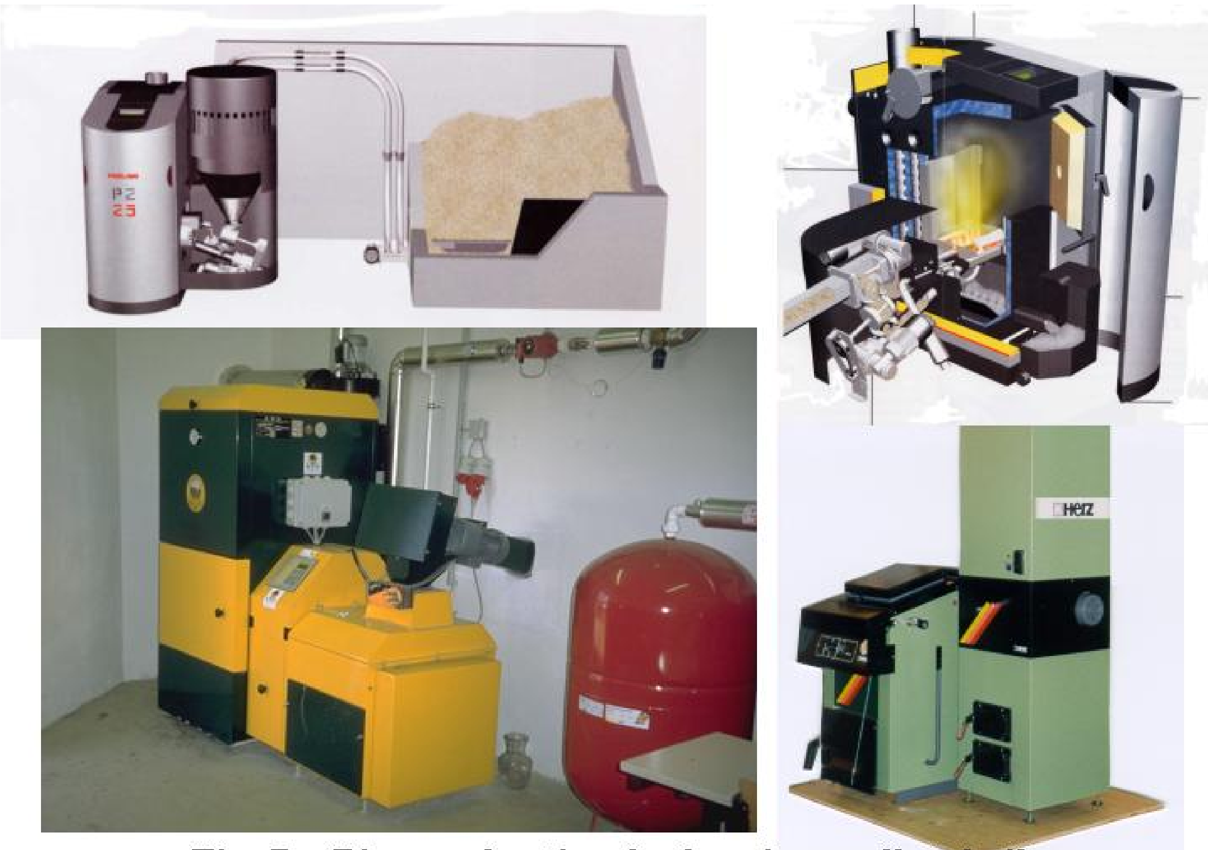


Fig. 7a: Biomass heating for housing: pellets boilers

Fig. 7b: Pellets boilers for decentalised heating

Fig. 8a: Solar-combined biomass heating in row houses (wood chips)

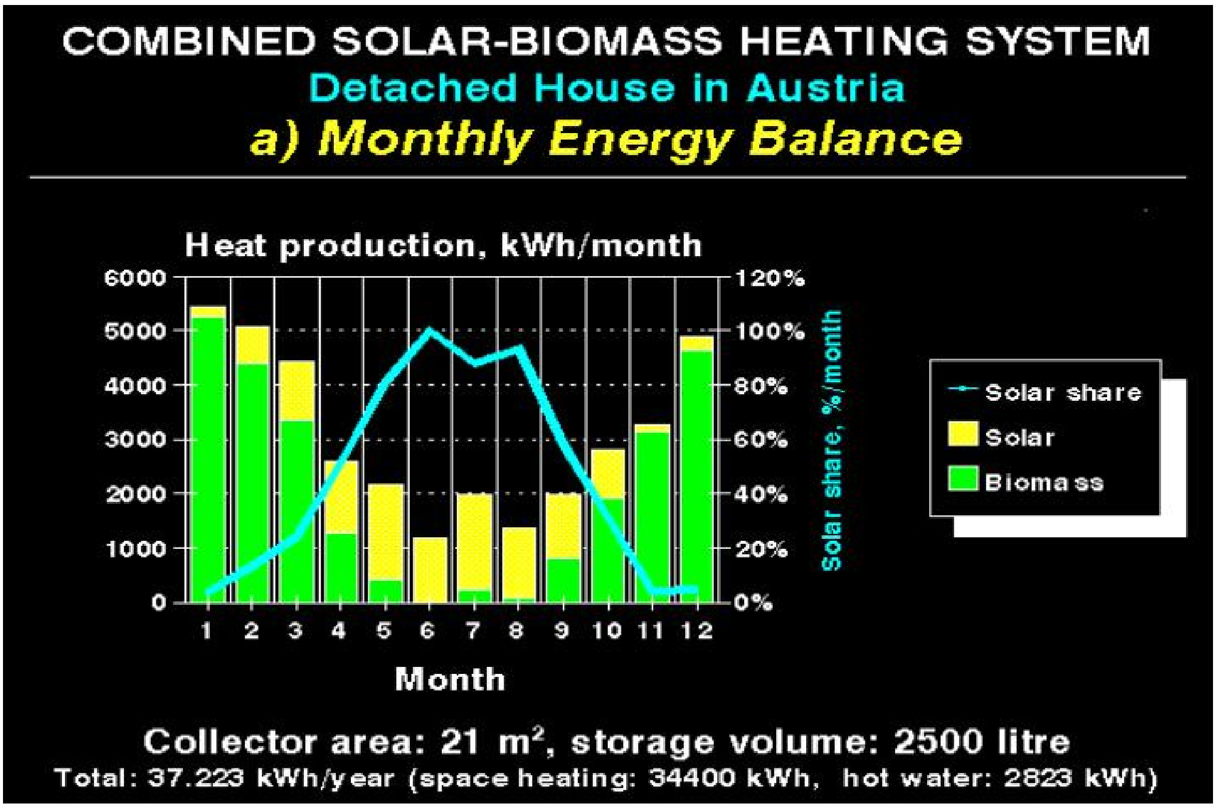


Fig. 8b: Solar-combined biomass heating in row houses (wood chips): Monthly energy balance

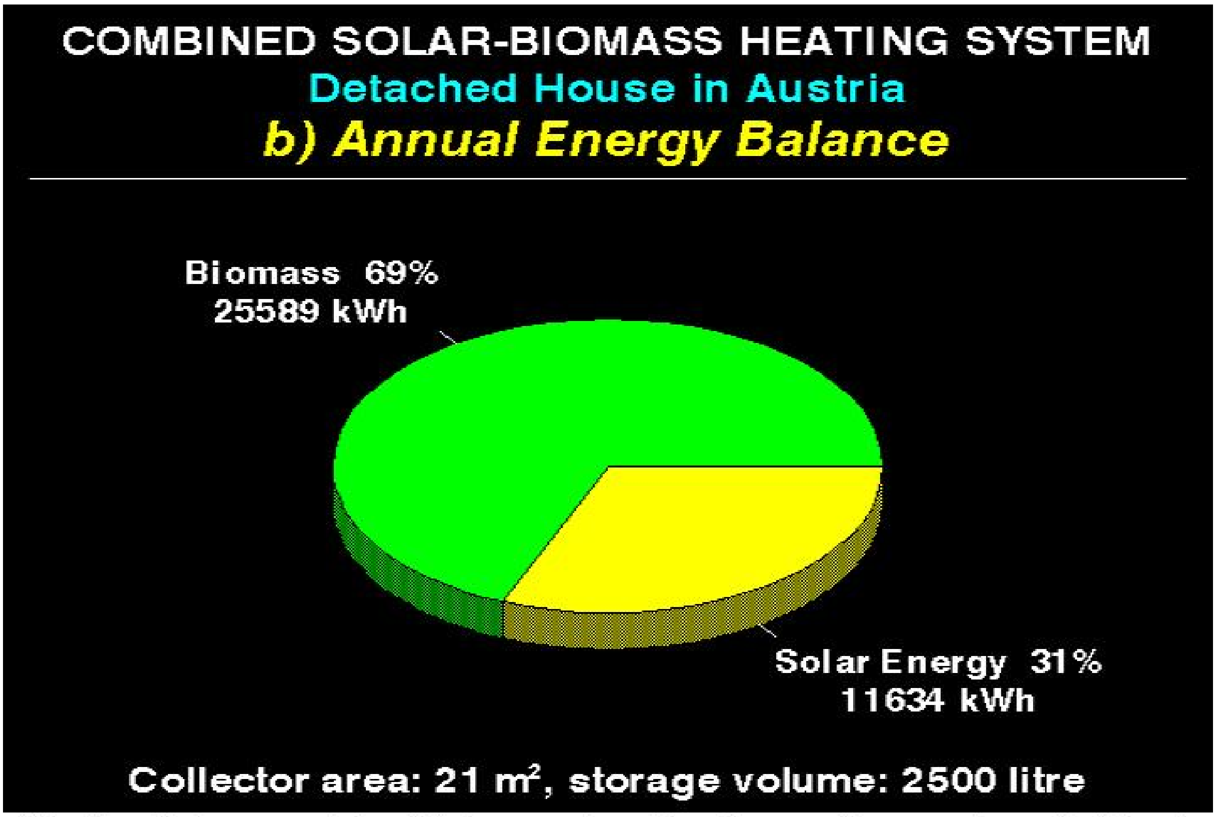


Fig. 8c: Solar-combined biomass heating in row houses (wood chips): Annual energy balance

Fig. 9a: Stores for pellets

Fig. 9b: Pellets heating system for housing estates

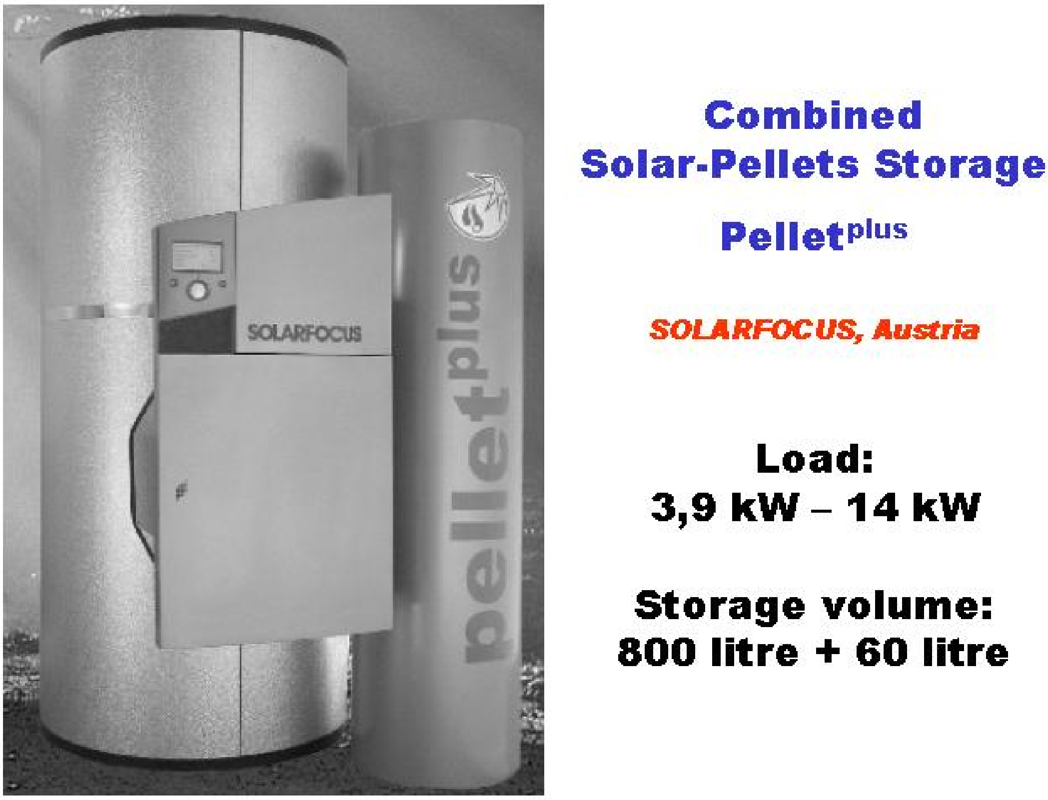


Fig. 10a: Combined solar-pellets heating unit

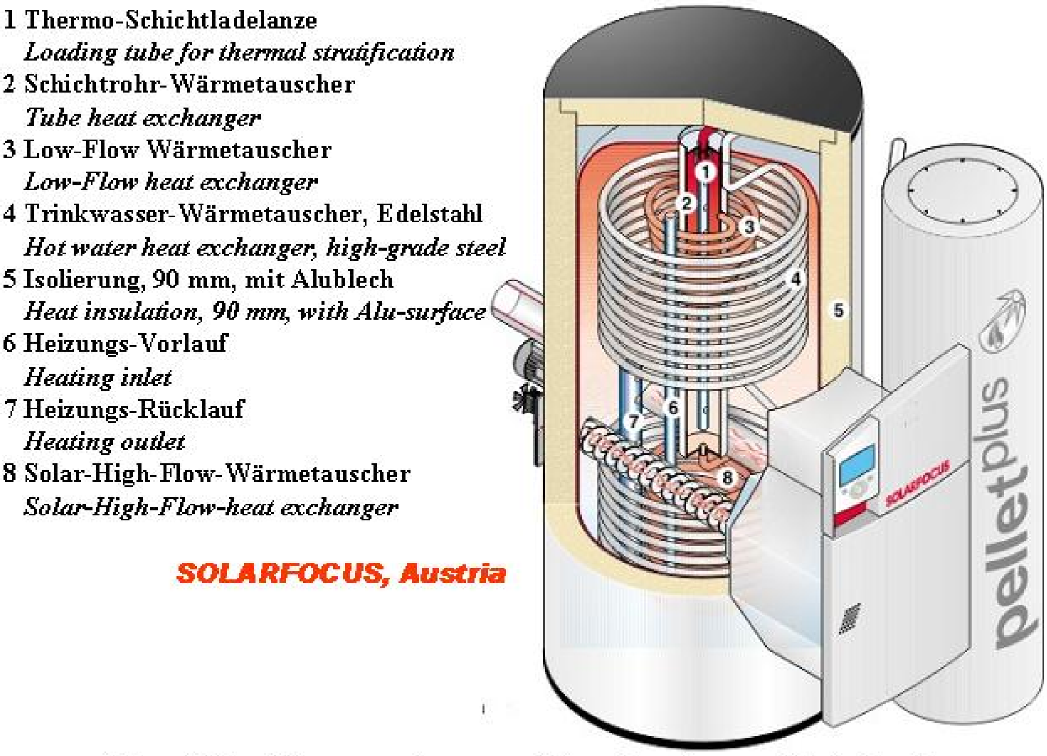


Fig. 10b: Storage for combined solar-pellets boiler

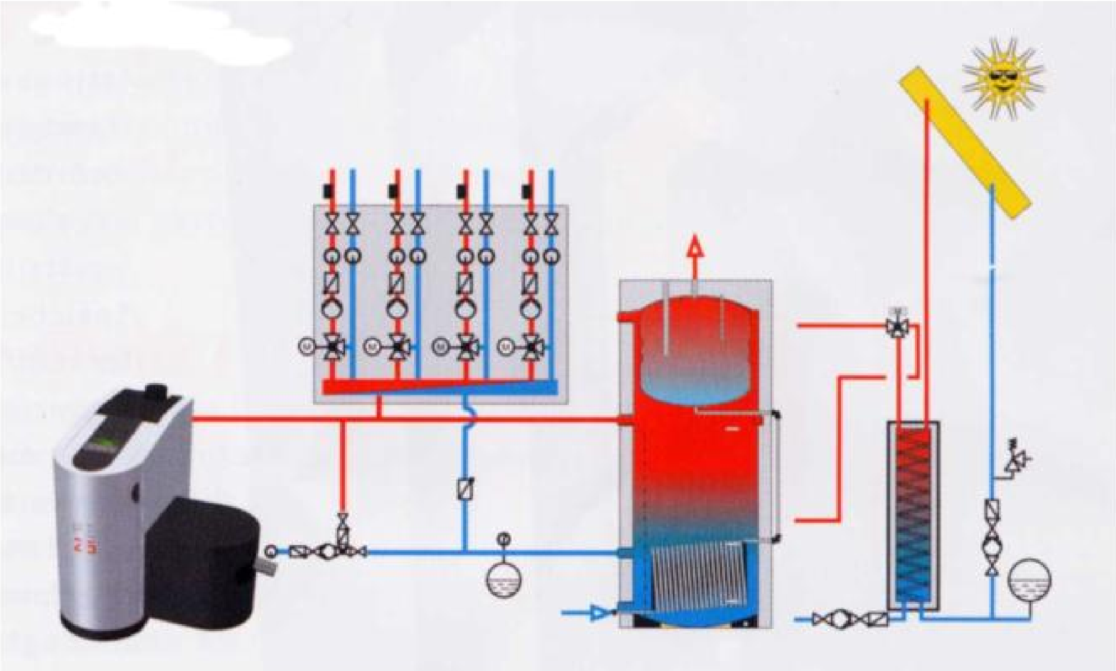


Fig. 10c: Combined solar-pellets heating system

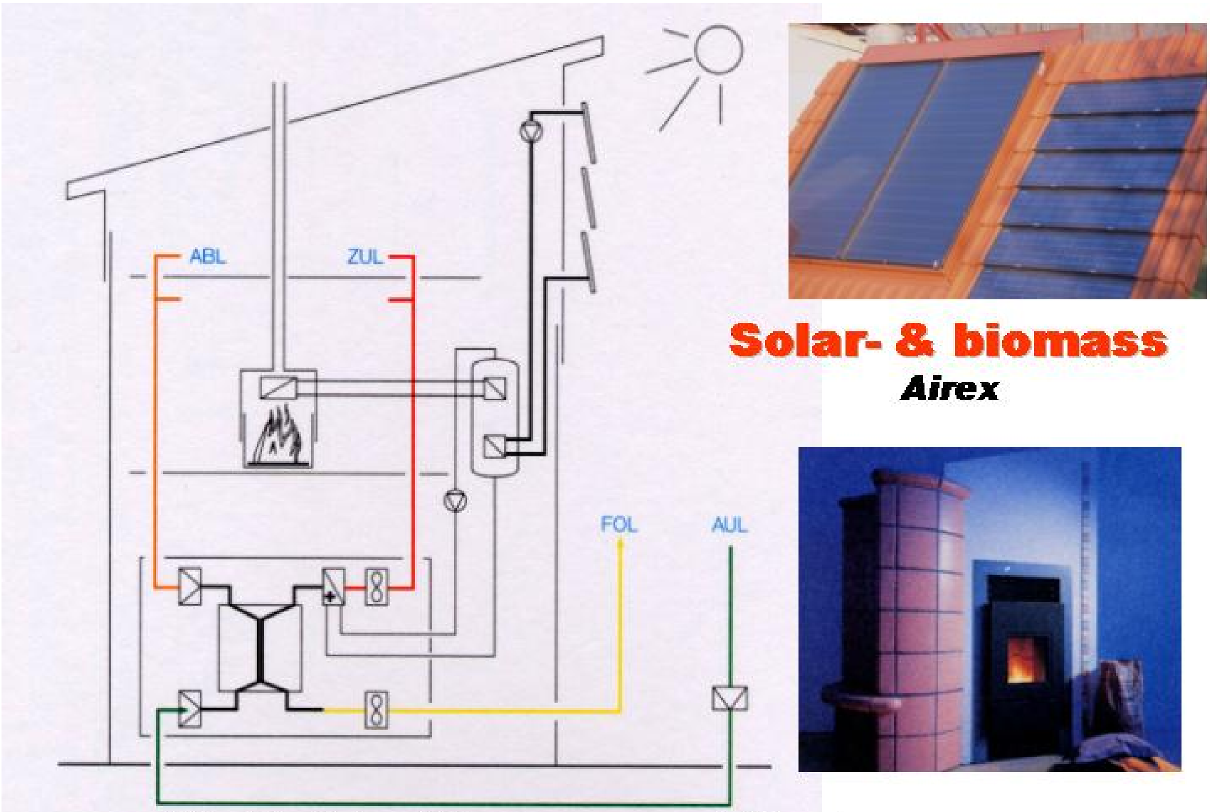


Fig. 11: Solar / biomass-supported heat recovery combined with air-heat pump

Fig. 12: Roof-integrated collector installation

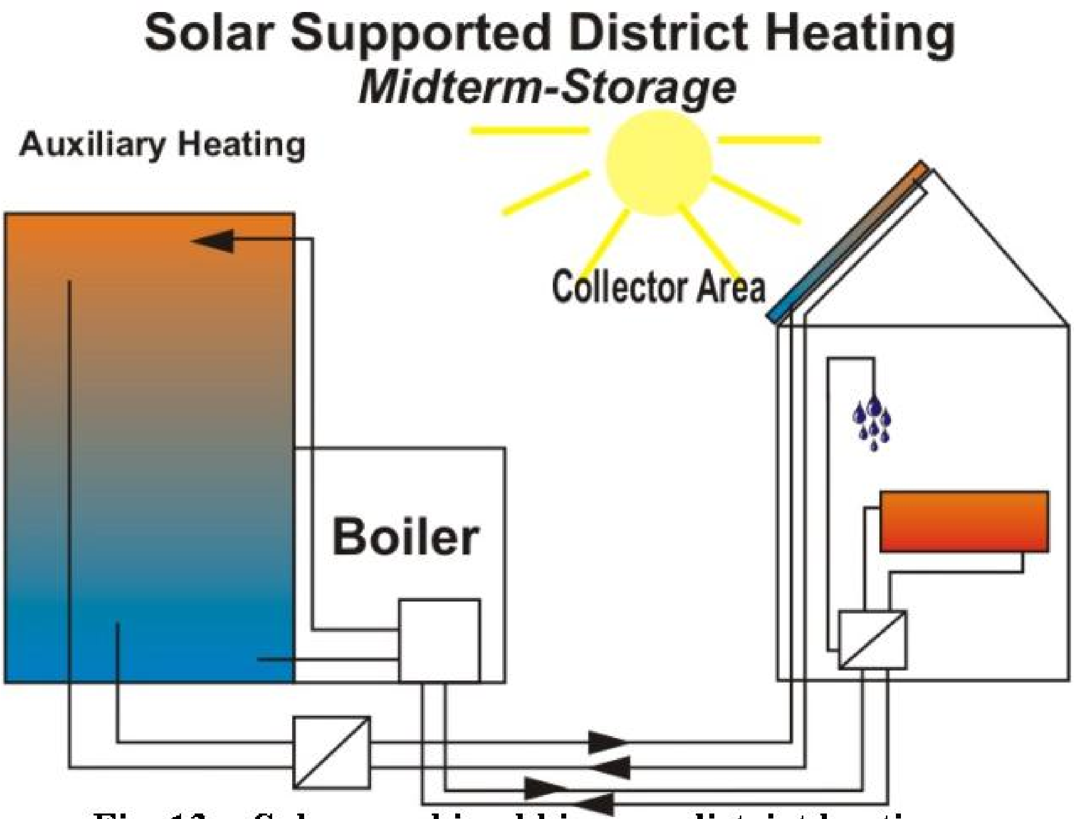


Fig. 13a: Solar-combined biomass district heating: Hydraulic schemata

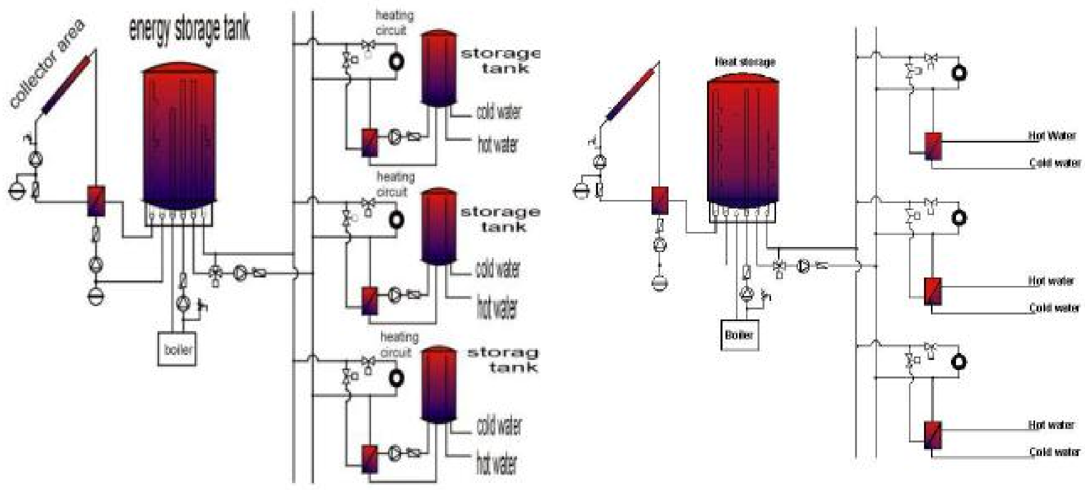
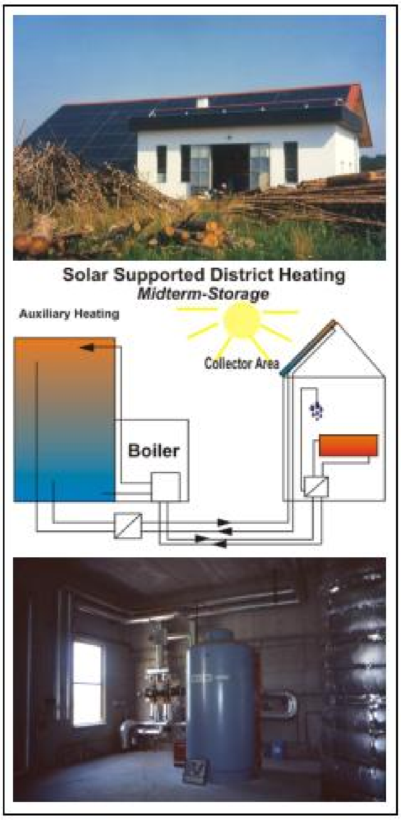


Fig. 13b: Solar thermal system with central storage in combination with decentralised hot water storages or heat exchangers: 2-pipe net

Fig. 14a: Solar-combined biomass district heating: Projects in Austria

Fig. 14b: Biomass boilers for district heating



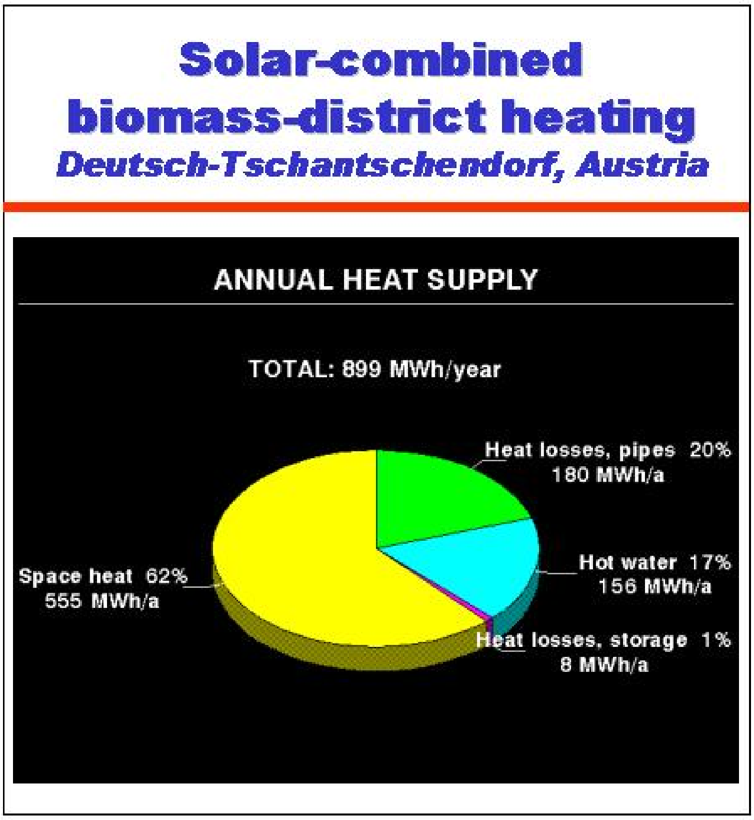


Fig. 15a: Solar-supported biomass district heating: Design principles

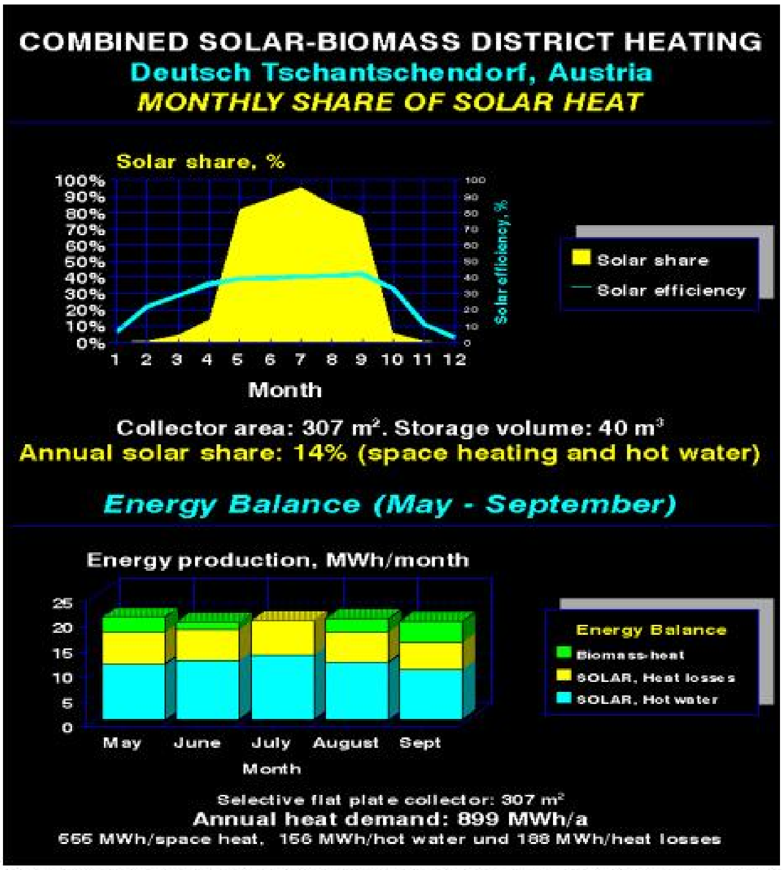


Fig. 15b: Solar-supported biomass district heating: Energy balance

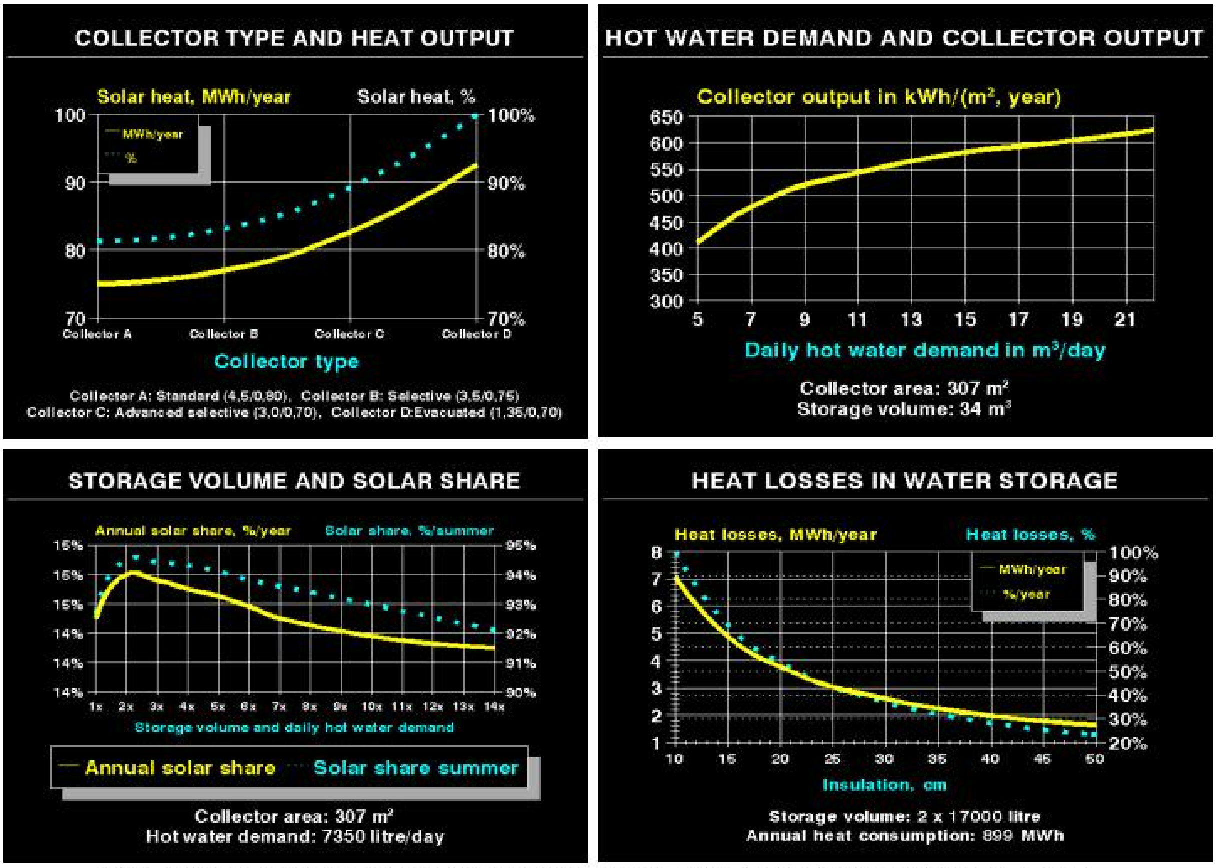


Fig. 16a: Solar-supported biomass district heating: Design principles

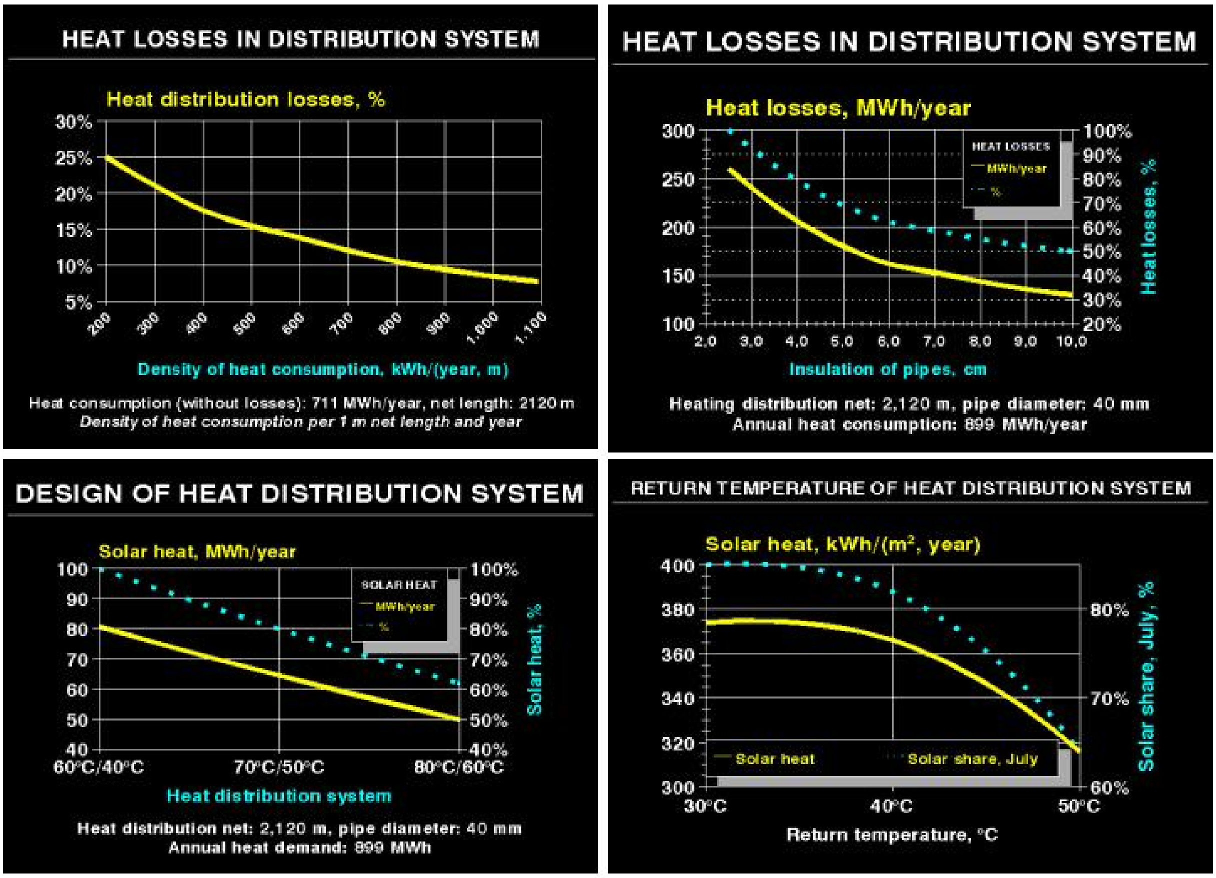


Fig. 16b: Solar-supported biomass district heating: Design principles