for business
bioenergy

Biomass in-house boilers
for potential operators/investors

European Commission

Horizon 2020
European Union funding
for Research & Innovation

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Table of contents

1. About Bioenergy4Business (B4B)

The Horizon 2020 project Bioenergy4Business (B4B) aims at supporting and promoting the (partial) substitution of fossil fuels (i.e. coal, oil, and gas) used for heating with available bioenergy sources (e.g. by-products of the wood-based industry, pellets, and straw) in the project partners' countries and beyond.

The objectives of B4B are:

- To identify the most promising commercial market segments for which a switch from fossil fuels to bioenergy is advisable
- To prepare business strategies and models
- To deliver know-how on the supply and usage of biomass
- To train developers, consultants, heat operators and employees of energy services companies to assess and develop projects in communities with district heating and in sectors with auto-production of heat
- To convince stakeholders of the opportunities that are created by local value chains for bioenergy heat
- To make the relevant policy makers aware of policy measures, that could speed up the bioenergy heat technology diffusion process

This will result in the project building bridges between policies and markets, to support the creation of an enabling environment that uses sound business and financing models, together with careful assessment and implementation, to facilitate the switch to bioenergy heat in local and district heating and in "in-house" applications.

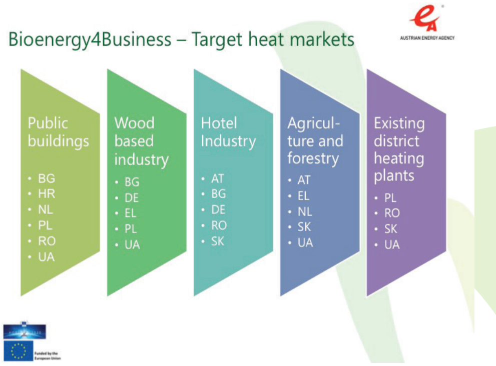
Bioenergy4Business involves partners from 12 EU Member States and Ukraine. 11 of these project partners (AT, DE, BG, CR, FI, GR, NL, PL, RO, SK and UA , except BE and DK) are target countries, where tailor-made activities for the most promising market segments will take place from January 2015 until August 2017.

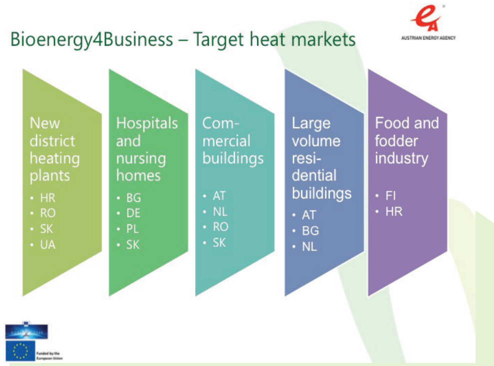
Contacts

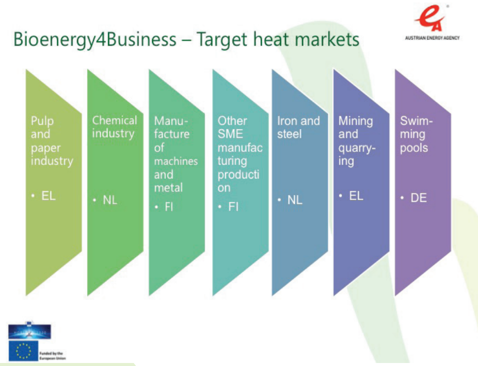
To obtain further information regarding the projects described in the brochure contact the Bioenergy4Business project team, or visit our website at www.bioenergy4business.eu

2. Promising Heat Markets

Among the project partners' countries the following most promising market segments for heat-only utilization of solid biofuels were identified. Most promising markets are:





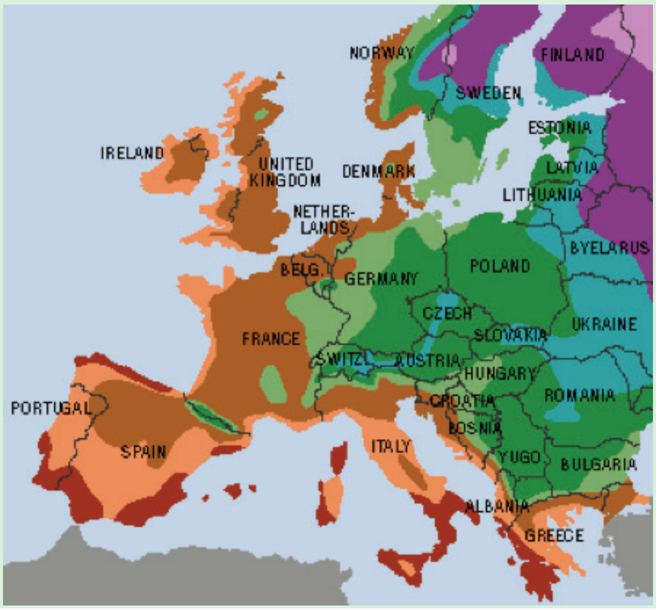


3. Biomass for in-house heating applications

There are many reasons for heating with biomass. In a nutshell, it is an environmentally friendly, price-competitive and locally available fuel. Within the past 20 years, biomass boilers have undergone vast developments towards highly efficient, clean and user-friendly systems that are today among the most preferred technologies for heating. Policy makers have helped to trigger technological developments in a different direction than fossil fuel heating systems but rather towards modern biomass heating systems.

State of the art biomass boilers burn high quality wood fuels such as pellets, wood chips, or agricultural and industrial biomass residues. Automated feeding and control systems make the use of these fuels as comfortable as any other comparable oil or natural gas fired system. Modern combustion control systems and flue gas cleaning technology result in low emission profiles, compared to modern oil or gas fired boilers.

There are large differences in terms of how bioenergy is used among EU28 countries. Western- and Northern-European countries for instance have been the frontrunners in this technology for the past decades, even though Eastern-European countries have great potential regarding bioenergy due to the local availability of biomass and a greater need for heating (Figure 1). The use of bioenergy for heating of large buildings (i.e. schools, hospitals, public and residential buildings) is an ongoing trend all over Europe and the market for in-house biomass heating systems is rapidly growing. Biomass boilers range in size from a few kilowatt (kW) for houses or small commercial/public buildings, to megawatt (MW) size units for district heating systems.



Average Annual Minimum Temperature		
Zone	Farenheit	Centigrade
3	-40 / -30	-40 / -35
4	-30 / -20	-35 / -29
5	-20 / -10	-29 / -23
6	-10 / 0	-23 / -18
7	0 / 10	-18 / -12
8	10 / 20	-12 / -7
9	20 / 30	-7 / -1
10	30 / 40	-1 / -5

Figure 1. Climate Zones in Europe and average annual minimum temperature [1]

4. Biomass boilers

Modern biomass boilers can operate at boiler efficiency levels comparable with modern gas condensing boilers. They are a very common technology in many European countries, especially in Austria, Sweden and Finland. Today, a broad choice of biomass boilers in different sizes and degrees of automation and fuel types are available in different price segments and qualities.

Biomass boilers can be categorised according to their fuel type (i.e. wood logs, wood chips, wood pellets). They are optimized for a specific biofuel type and will usually burn other fuel types inefficiently.

Most modern biomass boilers are automated and the fuel is fed automatically from the fuel storage, either by using an auger screw system or a hydraulic one. The fuel is ignited in the combustion chamber while a regulated flow of oxygen ensures an efficient and complete combustion. The hot combustion gases are led over the surface of a heat exchanger to heat up water. The hot water can either be used directly or can be stored in water tanks (i.e. buffer storage). Buffer storages help to cover peak loads and lead to a more constant and energy efficient operation of the biomass boiler, as the boiler has less but longer periods of operations.

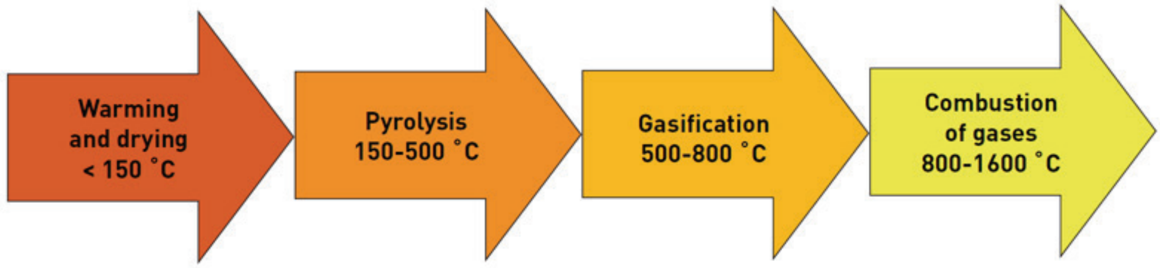


Figure 2. The four stages of a biomass combustion process [2]

Biomass boilers are as controllable as modern gas condensing systems: heating controls allow the user to adjust all personal parameters for the central heating and domestic hot water.

The biomass combustion process

The basic principle behind all biomass boilers' operation is the same. The biomass combustion process can be divided into four stages as shown in Figure 2.

> *"Biomass boilers are as controllable as modern gas condensing systems: heating controls allow the user to adjust all personal parameters for the central heating and domestic hot water."*

The ignition of biomass in the boiler usually occurs by electric heating / hot air drying of the biomass on the grate and the subsequent heating process until the ignition temperature is reached (approx. 400 °C).

In the first stage of the process, the combustion chamber must be hot when biomass enters the grate. Biomass boilers usually contain some refractory material to facilitate this. Boilers designed for handling biomass with a high moisture content feature substantial refractory linings.

Most of the energy bound in the biomass is released in the 4th stage, when the combustible gases, released in the 3rd stage, burn. This is mainly a mixture of carbon monoxide and hydrogen, burned at a high temperature.

Figure 3. Set-up of a modern biomass boiler, with fan and lambda sensors. As an example a Guntamatic Powerchip boiler [3]

A separate control for primary air (from beneath the grate) and secondary air (gas combustion) allows a temperature stirring in order to have high temperatures and turbulences in the gas combustion area (to ensure a complete oxidation of the biomass gases) while the temperature at the grate is significantly lower. The oxygen content in the gas combustion area is often monitored using a lambda sensor to minimize the formation of soot, CO and NOx and to maximize the thermal efficiency.

"Efficient and complete combustion is a prerequisite of using biomass as an environmentally friendly fuel."

The moisture level of biomass is important. A water content in the fuel that is too high may lead to incomplete gasification, resulting in black smoke and tar accumulations. Tar deposits on the heat exchangers and combustion chamber can be avoided or driven off by sufficiently high working temperatures.

Efficient and complete combustion is a prerequisite of using biomass as an environmentally friendly fuel. To ensure a high rate of energy efficiency, the combustion process should therefore be complete in order to avoid the formation of environmentally harmful compounds like unburned gases and fine coal particles.

The basic conditions to ensure a correct combustion are therefore:

- A correct mixture of biomass and oxygen (combustion air) in a controlled ratio, which corresponds to a recommended 1.4 Lambda. This means that it is necessary to use 1.4 times more combustion air than theoretically necessary to ensure a complete combustion;
- A correct distribution of primary and secondary air by correctly regulating air pressure and positioning the air nozzles;
- A correct design of the combustion area where the biomass has to be dried, heated, burned and finally end up as ashes before leaving the grate to the ash handling system. 75%–80% of the energy in biomass is burned as volatiles in the combustion chamber and the remaining 20%–25% glow away as charcoal on the grate.

Closed biomass stoves and boilers require flue liners due to a more concentrated smoke and a higher moisture content in the exhaust gas that can result in condensation of tars. Any existing chimney has to be lined to avoid damage to the bricks and running of condensate back into the combustion system causing a fire hazard. Lining can be done by inserting stainless steel flue liners, using a pumped refractory concrete lining or by adding a clay or concrete liner. National building regulations require and specify a minimum flue height to be used. If an automated flue cleaning system is installed, a significant reduction in boiler downtime and in maintenance time is possible, reducing manual flue cleaning from a weekly to a six-monthly exercise. The cleaning system consists of a series of compressed air jets or nozzles installed in the ends of the flueways.

They are pulsed in succession at regular intervals to automatically blow soot from the boiler while it is in operation. The system requires a small compressed air supply in the boiler house.

If the air supply to the boiler is insufficient, the boiler can generate an under pressure in the room where it is installed. A lack of oxygen in the combustion chamber will result in an incomplete combustion and in the release of carbon monoxide that could spill in the boiler room, creating a toxic atmosphere harmful to the occupants of the building.

"Once a year a full internal and external inspection of the boiler should be performed by authorised service personnel."

Once a year a full internal and external inspection of the boiler should be performed by authorised service personnel. The user should make regular visual inspections of the boiler, emptying the ash bin, greasing the induced draught fan bearings and manually brushing the flueways.

The most common types of biomass burners are Stoker burner boilers, underfed Stoker boilers and moving grate boilers.
Stoker burner boilers have a simple design and a relatively small grate attached directly to the end of a feed auger as shown in Figure 4. They are usually fed with wood chips with low moisture content and pellets. For this boiler type there is a risk of burn-back along the auger into the biofuel storage that can be eliminated by emptying the auger after shut down and/or by installing flap valves. The distinct supply of primary and secondary air to the different combustion zones can be a challenge for this boiler type unless multiple fans are installed.

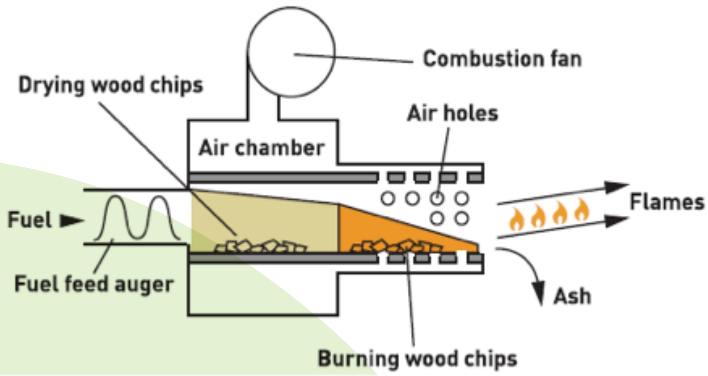


Figure 4. Stoker burner [2]

Underfed Stoker boilers have a different design. The fuel is pushed up through an inverted cone to form a dome of fuel on which combustion will take place. The auger is led into the boiler beneath the combustion chamber as shown in Figure 5. Since the feed supply comes from beneath and the combustion occurs upwards, the feeding system does not have to be emptied at shut down. Underfed stoker boilers are used for wood pellets and wood chips with low moisture content.

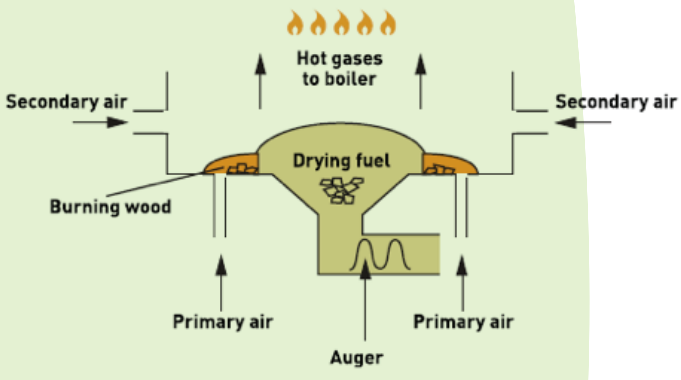


Figure 5.Underfed stoker boiler [2]

Moving grate boilers (commonly referred to as inclined or stepped grate boilers) have a much greater flexibility when it comes to fuel specifications - compared to Stoker boilers. An important feature of this boiler type is the tolerance of high moisture feedstock due to refractory lining areas installed in the boiler to enable a drying of wet feedstock.

Moving grate boilers use wood chips as fuel and can tolerate chips with up to 55% moisture content. Moving grate boilers require more space due to their design and refractory lining. They have multiple fans to support an optimal supply of air to the different combustion zones as shown in Figure 6.

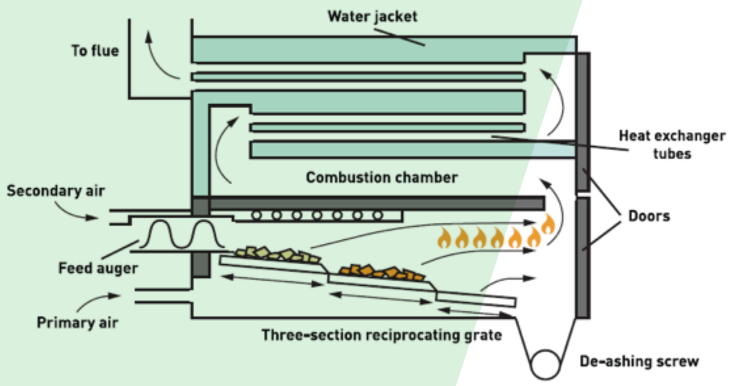


Figure 6. Moving grate boiler [2]


Figure 7. Example of a modern pellet-heating system from Biotech Energietechnik GmbH [4]

Pellet boilers

Pellet boilers are characterized by a high degree of automation. They are the closest to fossil fuel boilers in terms of maintenance and operation and a wide range of brands and manufacturers are competing on the market.

Pellets are usually fed automatically into the boiler system from a fuel storage using an auger screw system and a hopper. Pellet storage and boiler are often in separate rooms to reduce the risk of fire and for other safety reasons (i.e. dust, off-gassing, cleaning).

Pellet boilers are usually designed to use specific pellet types and qualities available on the market. In Europe, the pellet quality is defined by the EN-plus certification scheme, based on international standards for moisture content, chemical composition, mechanical durability, etc. Full efficiency can only be obtained when following the recommended fuel specifications.

Wood chip boilers

Wood chip boilers are widely used throughout Europe and have been on the market long before pellet boilers. Wood chip boilers are more tolerant to fuel specifications and can be supplied with chips with moisture content ranging from 10–35%. Moving or stepped grates allow the utilization of chips with moisture content up to 55%.

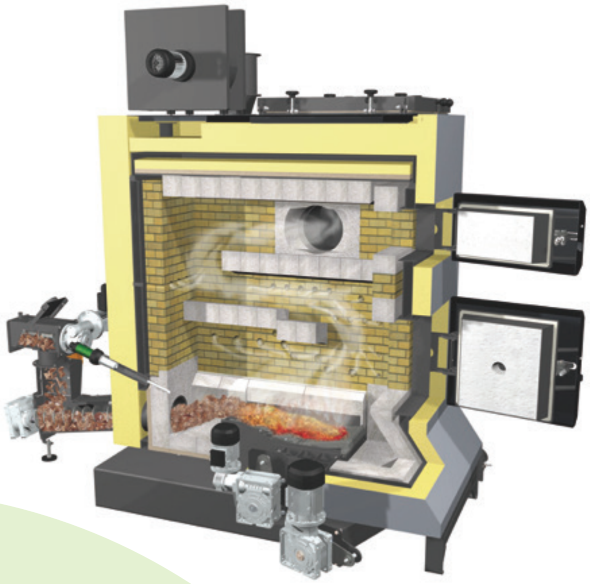


Figure 8. Wood chip heating system from Fröling Heizkessel- und Behälterbau GesbH [5]

5. Fuel types and handling

The quality of the wood fuel plays an important role for the combustion system and for the plant economy. In general, the smaller the system, the higher the quality demands for the used fuel. The highest quality wood chips for small installations can be made from small delimbed wood stems. Where lower quality chips can be fired, whole tree chips from non-delimbed small-trees stems can be used too. The key parameters that need to be specified are:

- Moisture content
- Dimensions of the chips
- Fines / dust content
- Origin of the chips
- Ash content

Wood pellets

Wood pellets are a globally traded commodity fuel and their fuel properties are defined by an international standard (ISO 17225-2).

Wood pellets have a defined size, shape and mechanical stability, which makes them easy to convey and transport by means of vacuum pumping. Pellets need to be stored dry: exposure to water will result in their disintegration.

In-house pellet boilers usually have a storage room or silo in connection with the boiler system from where the pellets are conveyed into the combustion chamber (See Figure 7).

The size of the fuel storage depends on various factors, e.g. available space, heat demand, seasonal price development of the fuel, and fuel supplier contracts. Usually, the fuel storage capacity does not exceed the amount used in one heating period and is often smaller. Especially, in existing buildings, the storage capacity may be limited to a storage supply sufficient for 1–2 months only. Usually, the storage capacity is a trade-off between storage and fuel delivery cost. However, it is always recommended to have a sufficient fuel reserve in case of unforeseen events such as extreme weather conditions or supply shortages.

For safety reasons (i.e. release of dust due to abrasion of small wood particles potentially dangerous to humans) the pellet storage should ideally be separated from the boiler and living area of the house. The greatest risks related to the storage of wood pellets are fire, dust and gas emissions. The storage room itself should not contain any possible ignition sources (electrical fittings etc.) and ideally meet ATEX specifications.

Wood chips

Wood chips are more tolerant to moisture since they can be stored outside for a limited time. Wood chips with high moisture contents (> 30%) may degrade in the storage. Microbial activity in the storage may result in self-heating and self-ignition of the feedstock. The potential for this to occur will depend on a number of factors, including the moisture content of the chips, ambient conditions and the store design. Reducing the height of the piles, a proper ventilation and regular turning of the piles allowing the heat to dissipate will reduce the risk for self-heating and ignition.

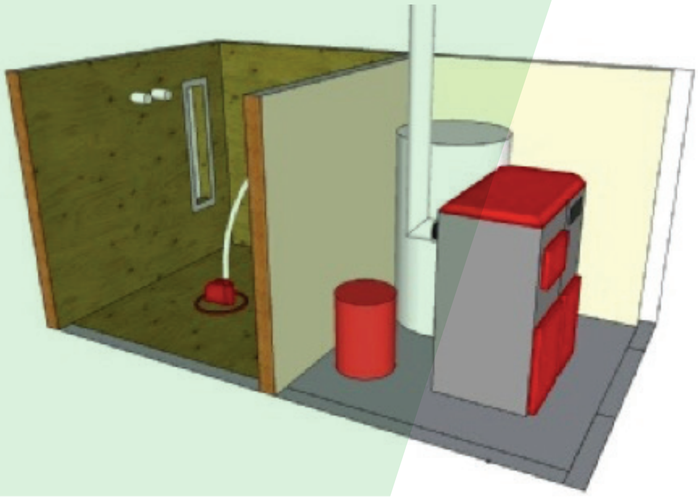


Figure 9. Example of wood pellet storage with vacuum suction system from Biotech Energietechnik GmbH [4]GmbH [4]

The quality of wood chips, just like wood pellets, is defined by international standards under ISO 17225. Wood chips have a lower bulk density and a larger variation in raw material, size and composition than pellets.

6. Planning and installation

From an economical point of view, in-house bioenergy heating systems are competitive solutions when compared with fossil alternatives. Higher investment costs are often compensated by national subsidies and by the operational costs (i.e. fuel price is lower compared to fossil heating systems). In addition, the specific investment costs decrease with increasing boiler sizes, i.e. the higher the heat demand, the greater the share of the fuel cost is on total costs. This implies that the economic advantages of using bioenergy heating systems increase with the heat demand. Higher maintenance costs are compensated by lower fuel costs. An important question to be addressed is the production of warm water. This can be either produced all year around using the biomass boiler, or only during the heating period with an alternative heating method outside the heating period.

Bioenergy heating systems are suitable for new buildings and for replacing fossil fuel boilers in existing buildings. A careful planning and preparation of the entire in-house bioenergy heating project is of utmost importance and professional advice should be sought for system dimensioning and implementation.

"Planning of the project and communication between the involved parties is a key factor for success. "

Planning of the project and communication between the involved parties is a key factor for success. Bioenergy heating systems require more space for the boiler, storage and delivery entrance compared to heating systems based on oil or gas – the access for trucks via appropriate streets is essential for instance (turning radius, free height for unloading wood-chips etc.). In addition, the availability of biomass fuels and their seasonal price development should be taken into consideration – biomass is often cheaper during the summer months than in the winter period with high fuel demand, it is therefore often apt to consider fuel supply contracts covering more than one year.

Dimensioning

The power rating of the boiler needs to be in line with the needs of the building if it is to be operated economically and efficiently, and it is therefore important to perform accurate calculations of the heat-load. These calculations are subject to change when, for instance, the building's insulation is improved – since improving the insulation of a building will increase the importance of the hot-water requirements.

The most important parameter for selecting and measuring heating systems is the heat load, which is a combination of heat demand and hot water demand. As a rule of thumb, the hot water demand is usually calculated at 12.5 kWh/m2 in residential areas, while the heat demand is a more complex function of location, degree days, insulation level etc. Commercial and industrial users have sector-specific demands in addition to these.

Over-dimensioning is one of the most common errors when planning a bioenergy heating project and usually results in extra costs. The boiler size is calculated to supply the maximum heat amount to the distribution net on the coldest day of the year. There is a calculation tool[6] available on the Bioenergy4Business project website to determine the boiler size based on geographic location, insulation level, fuel type and heat demand.

However, it is recommended to seek professional advice to ensure the right planning, dimensioning and set-up of the heating system. Errors made in the planning phase, especially wrong dimensioning and choosing the wrong technology will result in extra costs throughout the whole lifetime of the heating system, including fuel storage planning.

Selecting the right boiler

Space – If there is limited space on site, the storage of wood fuel could be a restriction. Wood chips will occupy up to three times more room than wood pellets for the same weight of wood. Biomass boilers also tend to be larger than conventional fossil fuel boilers, so users will need to have a large enough space to house the unit.

Size of the property – Typically, the larger the building is, the greater the requirement for space heating, and therefore the larger the boiler needs to be. Larger systems will consume more fuel and therefore tend to be automated systems with minimal manual intervention.

Access – For most systems, a fuel delivery vehicle will need to access the project site. Fuel can be delivered in a variety ways, however for bulk chips and pellet orders direct access to the fuel store is critical. For small domestic deliveries, it is important to have a dry place to stack logs or store bags of pellets. Projects in urban areas will need to be mindful of the number of fuel deliveries (large vehicle movements) necessary throughout the year as this may have planning implications.

Fuel supply – Users can choose their own fuel supply, in which case using logs, bark, or chips would dictate the boiler type. Generally, if space and access are not a problem, the use of wood chips would be considered for larger projects; however if space is scarce or if the area is sensitive to a greater number of fuel deliveries then pellets are the preferred option.

7. Examples

All examples (incl. photographs) used in this publication are taken from cases highlighted in the Bioenergy4Business report "Report summarizing best practice examples and conclusions", which is available to public on the Bioenergy4Business project website [7].

Example 1: Romania – Pellet boiler in the Technical College in Carasan City

The city council of Resita County has financed the installation of a pellet heat production unit in the Technical College in Carasan city following the decision to disconnect from the existing DH grid (the old distribution network of Resita County). Two pellet boilers of 100 KW each were installed. The plant uses all the heat produced to cover the internal needs of the school.

- Two pellet boilers each rated at 100 KW;
- Biomass supplied locally from the company "Romstal" located 3 km away;
- The plant uses all the heat produced to cover the internal needs of the school;
- Financed by city council via the local budget – total investment €58,000;
- Usage: 3.5 tonnes of pellets per year;
- The implementation and realization of the project has encountered no difficulties

Example 2: Bulgaria – In-house biomass boiler in the kindergarten Elhitsa

Municipality buildings have significant potential for energy savings and for the implementation of EE investments. Before the realization of the project, heating was supplied by a heavy oil-fueled boiler located in the ground floor of the kindergarten. The kindergarten is brick construction with a total surface area of 1,299 m^2 and a heated volume of 3,637 m^3.

- 230 kWth boiler supplied by D'ALESSANDRO-TERMOMECCANICA;
- Usage of 112 tonnes of pellets per year;
- The boiler and the ancillary equipment are situated in a 20-feet metal container with thermal insulation – an energy cabin!

Example 3: Greece – Fuel switch in the Komotini Paper Mill S.A.

This installation makes the company one of a handful, and perhaps unique in its size cluster, at European level as far as sustainable manufacturing of paper goes. The next goal is the tri-generation of electricity, steam as well as diathermic oil to further increase output of the machines and to reduce its footprint.

- Replacing heavy fuel oil boiler with a 8 MWth biomass boiler;
- Replaced 11t of fuel oil per day;
- Current usage: 25t of sunflower pellets per day;
- The waste (ash) from the energy production is reused as fertiliser;
- Yearly emission reduction of 11,000 tonnes of CO_2 equivalents.

Example 4: Croatia – In-house biomass boiler in the salt factory Solana Pag

The salt factory 'Solana Pag' is the largest producer of sea salt in Croatia, with a millennial history. Due to the very large share of energy costs in the total price of salt production, its viability was in danger, which motivated the owner to consider replacing the oil boiler with a biomass boiler of 10 MW (heat) capacity.

- Replacement of the fuel oil boiler with a biomass boiler of 10 MW (heat) capacity;
- 14-year supply contract, resulting in stable and low fuel costs (€40 per tonne);
- Current usage: 13,800 tonnes of wood chips per year.

Example 5: Poland – In-house biomass boiler in a school complex in Siedlin

Biomass fuel is acquired from local farmers, and the ash is returned to them to use as fertilizer – an example of a project that is environmentally, socially, and fiscally sustainable!

- The school complex was previously heated by a coal fired boiler;
- Replaced by a straw fired boiler with a capacity of 300 kW;
- Usage: 15 tonnes of straw are required annually;
- The investment came from the Siedlin municipality and national funds;
- Developed by a local heat plant engineer.

Example 6: Ukraine – Construction of a 7 MW boiler house for woodchips in Kniazhychi

A turn-key greenfield biomass plant, which has proven to be the right design choice. The project implements the concept of a full cycle of production and supply of thermal energy.

- One boiler house with two biomass-fired boilers;
- 7 MWth total capacity;
- 58,000 MWh of energy sold per year;
- Provides heat energy to greenhouses where flowers are grown (11 ha area);
- Storage located close to the boilers;
- Ash is used by the greenhouses as fertilizer;
- Usage: 7,200 tonnes of woodchips per year, delivered from nearby saw mills.

Example 7: Denmark – Fuel switch at the Sindballegard farm

Sindballegård is an upper medium-size Danish farm hold of 370 hectares. The farm produces traditional field crops together with raising of piglets and poultry. The new owner replaced the oil burner with a 450 kW straw fired boiler.

- Standalone unit including chimney, pumps, controls and the buffer tank;
- Designed for round bales, which are stoked manually using a farm tractor with a front loader – a practical process for the farmer;
- Supply of biomass covered from the farms' own production;
- The ash is reused as fertilizer in the farm's own fields;
- Annual production of 1,030 MWh;
- Usage: 255 tonnes of straw per year.

8. Contacts and references

Contacts

Get in touch with your national B4B contact point:

AUSTRIAN ENERGY AGENCY (OSTERREICHISCHE ENERGIEAGENTUR) *Austria* http://en.energyagency.at	**AEBIOM (THE EUROPEAN BIOMASS ASSOCIATION)** *Belgium/Europe* www.aebiom.org	**CENTRE FOR RENEWABLE ENERGY SOURCESAND SAVING FONDATION (CRES)** *Greece* www.cres.gr/kape/index_eng.htm
DEUTSCHES BIOMASSEFORSCHUNGSZENTRUM GEMEINNUETZIGE GMBH (DBFZ) *Germany* www.dbfz.de/aktuelles.html	**KRAJOWA AGENCJA POSZANOWANIA ENERGII SA (KAPE)** *Poland* www.kape.gov.pl/index.php/pl	**ROMANIAN ASSOCIATION OF BIOMASS AND BIOGAS (ARBIO)** *Romania* www.arbio.ro/en/#all
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ENERGETSKI INSTITUT HRVOJE POZAR (EIHP) *Croatia* www.eihp.hr	**MINISTERIE VAN ECONOMISCHE ZAKEN** *The Netherlands* www.rijksoverheid.nl/ministeries/ministerie-van-economische-zaken	**MOTIVA OY** *Finland* www.motiva.fi/en
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[7] Bioenergy4Business. Report summarizing best practice examples and conclusions. www.bioenergy4buisness.eu

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bioenergy

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AUSTRIAN ENERGY AGENCY

AEBIOM EUROPEAN BIOMASS ASSOCIATION

ARBIO

KAPE

ΚΑΠΕ CRES

DBFZ

Motiva

EIHP

Rijksdienst voor Ondernemend Nederland

DANISH TECHNOLOGICAL INSTITUTE

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Horizon 2020
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