MANUAL FOR EFFECTIVE UTILISATION OF BIOMASS
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MSc Velimir Šegon  
Ms. Tijana Šimek
NORTH-WEST CROATIA  
REGIONAL ENERGY AGENCY

Mr. Arturo Oradini  
Prof. Marco Marchetti
CSIG / UNIMOL

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MSc V. Šegon and Ms. T. Šimek are the authors of Chapters 1, 2 and 3;
Prof. M. Marchetti (University of Molise) and Mr. A. Oradini (CSIG) the authors of Chapter 4.
1. Introduction

The main focus of this manual is related to the possibilities of biomass use, technical aspect and implementation guide on how to manage biomass heating systems in municipalities and cities. These are the topics that are being analyzed and developed for many years in many countries but sometimes without significant steps towards project implementation. Looking at the results of dozens and possibly hundreds of district heating systems that are in operation in Austria, Slovenia, Italy and across Europe, it can be concluded that the great opportunity is missed and that some Adriatic countries do not use own potentials enough. It is hard not to draw parallels with other renewable energy sources - wind, solar, hydro power, which all recorded significant growth, new production facilities, but also a bright future in mind and planned projects in the developing world.

Successful use of biomass lies in small projects, in a large number of users and good organisation. Fuel wood is nothing new and it is used today throughout the Adriatic Countries but biomass in aspiration for developed and successful Europe means much more. Speaking of biomass, it includes fully automated boilers and pellet stoves, small, medium and large power plants that will warm entire villages or small towns, and also think of cogeneration plants in the timber industry, co-combustion in a conventional coal power plants and similar.

The wood biomass market for energy purposes in several Adriatic Countries is still in early stages of development except for logwood which has traditionally been used as a source for heating in households. One of the barriers for biomass market development, e.g. in Croatia, is the lack of financial incentives for investing in wood pellet heating and biomass district heating, but in spite of that woodchips and pellets are gaining on its popularity based on accessibility of cheap biomass boilers from domestic production and development of local pellet production.

Biomass production and utilization, bioenergy technologies, their market share, and research interests in these issues vary considerably between different countries and even within different regions of the same country. Nevertheless, in most of the countries socio-economic benefits of bioenergy use can clearly be identified as a significant driving force in increasing the share of bioenergy in the total energy supply. In most countries regional employment created and economic gains are probably the two most important issues regarding biomass use for energy production.

The essence of sustainability of bioenergy projects from a social aspect is how they are perceived by society, and how different societies benefit from this activity. Avoiding carbon emissions, environment protection, security of energy supply on a national level or other ‘big issues’ are for local communities an added bonus, but the primary driving force are much more likely employment or job creation, contribution to regional economy and income improvement. Consequently, such benefits will result in increased social cohesion and stability that stem from the introduction of an employment and income generating source.
1.1. What is biomass

Biomass consists of numerous, diverse products of plant and animal life, such as branches, twigs, bark and sawdust from forestry and wood, straw, corn stalks, sunflower stalks, remains in the pruning of vines and olives, pitted cherries and peel apples from agriculture, animal waste and residues from livestock farming, municipal and industrial wastes.

It is the most complex form of renewable energy. As a raw material comprising forest and agricultural biomass, biomass incurred during the production processes of various industries or waste in terms of communal waste, water purification and sewage sludge and it can be grown on energy plantations. As a final product - energy, biomass can serve as a renewable source for producing electricity, heat and fuel for transport. It is often the tendency to use “bioenergy” for biomass energy systems that produce heat and/or electricity and “biofuels” for liquid or gaseous fuels for transportation. Bioenergy can also be used for cooling using absorption chillers and also 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).

In the exploitation of biomass the essential step is the conversion of the initial feedstock into energy that can be liquid (e.g. biodiesel, bioethanol), gas (e.g. biogas) or solid (e.g. pellets). In addition, unlike other renewable energy sources, biomass can be characterized as conditional renewable energy. The basic requirement which should be met in this regard is the application of a sustainable approach, which can be demonstrated with an example of exploitation of forest biomass. If the entire forest is cut down for the sake of burning wood, obviously this is not a sustainable use and such use cannot be considered as a renewable energy source. If, however, uses only one part of the annual increment to ensure stable growth and the preservation of forests in the future, such exploitation of biomass is certainly among the renewable energy sources.

Biomass is already the most important source of renewable energy in Europe and has enormous potential for further development which should follow some basic principles, such as high conversion efficiency, competitiveness and sustainability. Experience proves that the use of biomass to produce heat in the best way meets the stated principles. Biomass for the production of heat may be used in small units, such as individual houses in projects contractual sales of heat for district heating and industry. In any case, high-quality supply of biomass, irrespective of whether wood fuel, wood chips or processed wood, it is crucial for rapid growth of this market.

Due to the high complexity and potential sources of raw materials, processes and processing technologies to utilize biomass, as well as the effects of exploitation on the environment, economy and society in general, in the selection of areas covered within this manual it was necessary to limit the scope of processed biomass sources technologies and exploitation. The basic criteria for selecting the treated areas were taken out of practical applicability or the possibility of using various forms of biomass. Given the significant potential of forest biomass and the current state of the use of biomass in the pilot areas of Holistic project, where the forest biomass is by far the most important source for obtaining energy from biomass, this area accounts for the largest part of the manual content.
1.1.1. Sources of biomass

Biomass, as already mentioned in former chapter, is a very broad term which is used to describe materials of recent biological origin that can be used either as 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, industrial (organic) by-products and the organic fraction of household waste.

Sources of biomass are thus very diverse and include, among others, the following:

- Forest biomass
- Biomass from wood industry
- Biomass from agriculture
- Animal residue (biogas)
- Energy crops
- Waste biomass

Forest biomass consists of residues and wastes resulting from regular forest management. The final products are made through the conversion of forest residues, chemical or other physical processes. Forest biomass used in heating systems vary from fuel wood to various products which are produced by treating wood and wood residues such as briquettes, pellets and wood chips.

Biomass from wood industry includes residues from sawing, grinding etc. and can be used as a fuel in their own boilers or as raw material for products such as briquettes, pellets or similar. This kind of biomass is much better than forest biomass since there is a smaller percentage of moisture in the wood. From economical perspective it is also a great advantage because of lowering operational costs of the involved industry in terms of maintenance costs and waste management.

Biomass for energy can also be harvested on abandoned farmland, where the energy potential of biomass depends on the stage of the land, as well as the period in which did not precede agricultural activities. Biomass from agriculture includes straw, corn stalks, seeds and fruit residues, residues of oil and many others. It is heterogeneous biomass of various properties, with low calorific value, high moisture content and different admixtures.

Animal wastes include manures, renderings, and other wastes from livestock finishing operations. Biogas is made through a process of anaerobic rotting. Commonly consists of about 60 % methane, 35 % CO₂ and 5 % mixture of hydrogen, nitrogen, ammonia, hydrogen sulfide, CO, oxygen and water vapor. Its properties as a fuel are closely related to the proportion of methane. Fuel value is directly proportional to the amount of methane and because of that the amount of air needed for combustion is less.

Energy crops are grown specifically for use as fuel and offer high output per hectare with low inputs. The prime advantages of energy crops are waste water, fertilizers and sediment (vegetation filters) usage, biodiversity and avoiding surplus in agricultural production.
They can be divided as following:

- Short rotation energy crops - poplar, willow, black locust and eucalyptus
- Grasses and non-woody energy crops - miscanthus
- Agricultural energy crops - sugar, starch and oil crops
- Aquatics (hydroponics) - microalgae, macroalgae, pond and lake weeds

Waste biomass includes green fraction of household waste, biomass from parks and gardens of urban areas and sludge from the wastewaters collectors.

![Forest biomass (Austria)](image)

**Picture 1. Forest biomass (Austria)**

### 1.2. Why is biomass a renewable and low carbon source of fuel?

In the last 20 years the world energy consumption has increased enormously. That means, along with the use of atomic energy, a significant increase in the consumption of fossil fuels. Slowing down the process and finally the inverse of the ever-growing demand for energy is one of the most important tasks of modern mankind. For reorientation there are two reasons: limited sources of fossil fuels and the growing burden of the atmosphere with the threat of global climate change and potentially fatal environmental pollution. As a special danger arises emission of carbon dioxide (CO\(_2\)). CO\(_2\), in conjunction with water vapor and other gases in traces, leaks short-wave Sun rays through the atmosphere, but absorb long-wave heat rays from the Earth. Thus, the lower part of the atmosphere warms and that process has become known as the “greenhouse effect”. The consequence is a global increase in temperature and increase of the content of water vapor in the lower atmosphere, leading to climate change with catastrophic consequences. For that reason it is also important not to fully exhaust fossil fuels because they are a significant source of raw material for the entire spectrum of “non-energy” products. One of the ways to produce energy without consuming fossil fuels and CO\(_2\) emissions is the use of biomass as a fuel.

It is very important to stress that 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 CO₂ that was absorbed as the plants grew over a relatively short period of time and there is no net release of CO₂ if the cycle of growth and harvest is sustained.

Using biomass as a fuel means that CO₂ 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.

When assessing the environmental impact of energy production from different fuels, it is most commonly to observe emissions of sulfur dioxide (SO₂), nitrogen oxides (NOₓ) and particulate matter. The combustion of coal and oil produces emissions of a number of other harmful compounds, among which the most significant emissions of heavy metals, while the emission of heavy metals by biomass combustion is negligible. The biomass can have a relatively greater amount of H₂S and chlorine, and in landfill gas a range of volatile organic compounds including halogenated hydrocarbons.

1.2.1. Biomass and environment

Every year agriculture and forestry generate huge amounts of biomass. The largest part of the agriculture products are dedicated to the nutrition of the population. A certain amount of biomass is used in animal husbandry for livestock or as litter and a part is used as a raw material in other industries while in the exploitation and maintenance of forests a large amount of biomass generated can be used for energy production. Recognizing the need to restore a certain amount of organic matter in the soil, there is still a considerable amount of biomass that can be used for energy production. The application of biomass derived from breeding plants has a number of advantages for the production of energy, but also some disadvantages. Biomass cannot provide coverage for all the energy needs of a country as large vast areas would be needed to grow quite certain plants. This would have a very negative impact on the ecosystem and biodiversity in nature and also reduce agricultural land and food production.

There are several types of energy plantations on which biomass for energy can be produced. The longest studied and best known are energy plantations of fast-growing trees in which the duration of rotation (time from sowing to harvesting) lasts from 3 to 12 years. In addition to numerous economic and energy aspects that need to be considered, the cultivation of energy plants have a definite impact on the environment.

The environmental impacts of energy plantations may reflect on the quality of water and soil, animal habitats, the separating CO₂ and biodiversity conservation. In the cultivation of energy crops is necessary to use fewer chemicals than it does in classic agriculture. In this way, the amount of chemicals in surface waters and the possibility of their penetration into the primary water are reduced.
Cultivation of energy crops over large areas would have a significant negative impact on biodiversity. But the fact is that biodiversity is significantly impaired by growing traditional crops, the raise of energy plantations on abandoned agricultural land would accounted a positive step in that direction.

1.3. Why use a biomass heating system?

For a complete evaluation of biomass as a renewable energy source, it is necessary to take into account a various range of different socio-economic consequences. Biomass effects on employment, creation of new and existing jobs, it increases local and regional economic activity and earning extra income in agriculture, forestry and the timber industry through the sale of biomass fuels. In addition, instead of the outflow of funds due to the purchase of fossil fuels, it establishes cash flows in the local community (investment-profits-tax). Impact on employment and, accordingly on the socio-economic aspects represents the most advantageous use of biomass compared to fossil fuels, but also to other renewable energy sources. Developed countries of the European Union and the world are aware of the positive effects and thus significantly boost projects using biomass energy.

1.3.1. Socio-economic impacts of bioenergy production

Biomass production and utilization, bioenergy technologies, their market share, and research interests in these issues vary considerably between different countries and even within different regions of the same country. Nevertheless, in most of the countries socio-economic benefits of bioenergy use can clearly be identified as a significant driving force in increasing the share of bioenergy in the total energy supply. In most countries regional employment created and economic gains are probably the two most important issues regarding biomass use for energy production.

Socio-economic impact studies are commonly used to evaluate the local, regional and/or national implications of implementing particular development decisions. Typically, these implications are measured in terms of economic indices, such as employment and monetary gains, but in effect the analysis relates to a number of aspects, which include social, cultural and environmental issues. The problem lies in the fact that these latter elements are not always tractable to quantitative analysis and, therefore, have been precluded from the majority of impact assessments in the past, even though at the local level they may be very significant. In reality, local socio-economic impacts are diverse and will differ according to such factors as the nature of the technology, local economic structures, social profiles and production processes.

The specified impacts represent a general overview of possible criteria which could be included in the sustainability aspects of biomass resource assessments from the socio-economic point of view. However, the definition of specific socio-economic criteria to be included in the analysis is dependent from the particular project and its background.

A short elaboration of some specific aspects regarding socio-economic sustainability issues is provided in the following text:
• Competition with the demand for food, feed and fibers

As the area globally available for agriculture is restricted, an expansion of biomass cultivation inevitably leads to an increased competition – above all with food production. There is a consensus that food security has to be given priority. The domestic food demand depends on two aspects – population growth and dietary preferences (i.e. the share of meat). Also the level of self-sufficiency needs to be considered – at least in studies on European and national level. Theoretically, all food needed in Europe could be imported which would free all agricultural land within Europe for biomass production. However, it has to be taken into account that importing food likely leads to indirect land use changes in other countries: If food production on existing (and restricted) agricultural land is not given priority the production of energy crops will lead to a displacement of food production to non-agricultural land – where land use changes of natural or semi-natural ecosystems might be caused. The same can of course happen in Europe if food production is not given priority and if the conversion of forest or grassland is not strictly excluded. These land use changes are to be seen as critical from a climate change and biodiversity point of view.

Although it is discussed less fiercely, there is also a strong competition for biomass used for the production of biomaterials such as wood as building material. Also this demand should be given priority as biomass currently is the only alternative source whereas for energy, other renewable sources are available such as solar or hydro power.

However, the final decision on the priorities regarding competition for food, feed and fibers and to what extent this decision should be left to the free market is within the responsibilities of different national governments (respecting of course international agreements). In that regard, this criterion should be applied at the global level and consequently bioenergy, food and biomaterials would be produced where it is economically most profitable.

• Creation of new employment (especially in rural areas)

The introduction of a net employment and income-generating source, such as bioenergy production, could help to stem adverse social and cohesion trends (e.g., high levels of unemployment, rural depopulation, etc.). It is evident that rural areas in some countries are suffering from significant levels of outward migration, which mitigates population stability. Given bioenergy’s propensity for rural locations, the deployment of bioenergy plants may have positive effects upon rural labour markets by, firstly, introducing direct employment and, secondly, by supporting related industries and the employment therein (e.g., the farming community and local/regional renewable energy technology providers, installers and service providers).

• Increased Standard of Living

In economic terms the “standard of living” refers to a household’s consumption level, or its level of monetary income. However, other factors contribute to a person’s standard of living but which have no immediate economic value. These include such factors as education, the surrounding environment and healthcare, and, accordingly, they should be given equal consideration.
- **Landscape and visibility of the countryside**

The introduction of short rotation coppice (SRC) often creates new and visible features on the countryside. It can have either a beneficial or negative impact on the landscape, depending on where and how it is grown. The actual impact will depend upon the character and quality of the recipient landscape, the extent of physical change involved, and the ability of the landscape to accommodate this change.

### 1.3.2. Biomass and employment

Global scenarios regarding the contribution of the bioenergy sector to employment generation are quite different. Most developing countries continue to use bioenergy in the traditional way. As this trend remains, unprecedented population growth adds more pressure to existing resources. Developed countries, on the other hand, continue to invest in RD&D in furthering advancement in bioenergy technology. International commitments to cut carbon emissions push frontiers and encourage the use of better and environmentally appropriate fuels in the years to come. Global climate change coupled with the convoluting realities of social, political, economic and environment issues make way for many challenges and opportunities.

Employment in the biomass sector can be of low-wage/training/capacity. The fact that more people are needed per energy unit is not necessarily a positive thing. Many biomass energy workers in developing countries would like to have other opportunities of employment to move up in the economic ladder. A comparison of the wages in both developing and developed countries would show that in developed countries the wood-energy worker earns the equivalent to many other technically qualified jobs and can have an average lifestyle. In developing countries the wood-energy worker will probably earn well below an average wage, being left in the lowest economic levels. Therefore, this paper approach is to modernize bioenergy systems in developing countries, maybe losing some jobs but raising economic level.

![Biomass transport (Austria)](image)

**Picture 2.** Biomass transport (Austria)
Direct employment results from operation, construction and production. In case of bioenergy systems, this refers to total labor necessary for crop production, construction, operation and maintenance of conversion plant and for transporting biomass. Indirect employment is jobs generated within the economy as a result of expenditures related to above mentioned fuel cycles. Indirect employment results from all activities connected, but not directly related, like supporting industries, services and similar. The higher purchasing power, due to increased earnings from direct and indirect jobs may also create opportunities for new secondary jobs, which may attract people to stay or even to move in. These latter effects are referred to as induced employment.

In Croatia the State owns 78% of all forested land or 2 018 987 ha, while the rest 22% or 581 770 ha are in the private ownership (National Forestry Master Plan, 2006). The Ministry of Agriculture, Forestry and Water Management is the administrative body responsible for the implementation of national forestry policy, while the state-owned company Hrvatske šume Ltd has a mandate to manage the state-owned forests according to the principals declared in the official documents that have to be approved by the Ministry and Government. Legal persons, other than Hrvatske šume Ltd, manage a minor area of state-owned forests.

The Law on Forests (OG 140/05, 82/06, 129/08, 80/10, 124/11, 25/12, 94/14) lays down the criteria for forest stewardship, minimal level of education for people employed in forest management as well as obligation for Hrvatske šume Ltd to define long-term and short-term management plans. Privately owned forests should comply with those long-term management plans, but this is not always the case. The reason could be found in the fact that private forest-holdings are highly fragmented: there are 599 056 forest owners with an average forest-holding of 0.97 hectares. Continuing, privately owned forests are often linked with the lack of professional knowledge in forest management and forest stewardship tradition, insufficient number of forestry associations, through which the forest-owners would exchange knowledge and experience, and coordinate forestry interventions. Their education about safety and proper procedures in forestry works is very low, usually they lack protective equipment and appropriate tools for performing forestry works and due to that, injuries and deaths are not uncommon. They usually have a strong motive to do works in their forests, related to fast profit and approximately 60% harvesting is illegal. That wood is mostly sold to the small local sawmills or for firewood by 20-30% prices lower than market prices. Finally considerable part of private forests is degraded and requires high investments for rehabilitation.

In the end some concluding remarks regarding socio-economic impacts of bioenergy utilization can be emphasized:

1. From a macroeconomic perspective, bioenergy contribute to all important elements of country development:
   - economic growth through business expansion (earnings) or employment;
   - import substitution (direct and indirect economic effects on GDP);
   - efficiency improvement;
   - security of energy supply and diversification.

2. Among other renewables, bioenergy is the most labour-intensive technology and has the highest employment-creation potential. The level at which it can contribute depends on local demographic and economic conditions. Other conclusions and findings include:
• the use of manual systems supplied the local economy with the highest earnings, while the use of mechanized systems gave the local economy only a fraction of the earnings since most of the revenues went to “outside suppliers”;
• large projects tended to give lower impact on employment than small projects;
• projects based on agricultural crops generated more earnings and employment. In EU, these projects are subsidized and performed on set-aside lands;
• investment cost per job created in the bioenergy sector is lower than average employment costs of industrial projects, petro-chemical industry and hydro-power;
• electricity production from bioenergy involve numerous potential external effects such as indirect socio-economic and environmental external impacts of the fuel cycles;
• the level of direct jobs needed for the operation of bioelectricity systems is about four times higher than the one required for the operation of fossil fuel power plant;
• bioelectricity production requires several times direct jobs than the production of nuclear electricity.

Picture 3. Company MITTERMAYR GMBH HOLZBAU (Austria)

2. Utilisation of biomass

2.1. Biomass fuels

The largest part of forest biomass comes from harvesting. Regular cutting is a part of the overall forest cycle while additional cutting is inevitable sanitary measure due to damage to the wood. For the evaluation of the potential yield of biomass it is necessary to know the growing stock and its share by tree species, age classes, diameter classes, increment, cut and similar indicators. These data are the foundation of the planning of forest residue in energy use.

Generally the biomass boilers use forest biomass wood chips, wood pellets, and residues from wood processing industry as fuel. In addition, it is possible to use the biomass of agricultural origin (straw,
kernel, shells, etc.), but in this case it is necessary to use a special boiler construction and the use of these fuels is still relatively rare.

2.1.1. Wood pellets

Wood pellets are small, compressed cylinders of dried natural wood which are produced in facilities for the production of pellets often associated with mills, enabling value-added exploitation of wood remains at the sawmill and wood processing industry.

Pelletizing is the process of thickening compacting sawdust, shavings and grinding waste without binder or chemical supplements. There is a possibility of producing pellets form wood bark, paper, sorted home garbage, agricultural crops, forest residues, fast growing energy wood and waste wood.

Pellet moisture is lower than 10 %, which gives it a high energy value. Cylindrical in shape and of different diameters they are perfect for household and small systems (diameter of 6 to 8 mm) and for larger systems (diameter of 10 to 12 mm). Due to the shape and size they are easily transported and simply filled into the furnace boilers used, for example, to heat buildings. The amount of energy that is obtained by burning 2 kg of pellets of that wetness is equal to a liter of fuel oil.

The quality of wood pellets is not defined only by selecting raw materials and production process. The quality of wood pellets is also affected by the transport and handling in temporary warehouses, as well as the delivery of wood pellets in silos or storage space of the client. Mechanical loading of pellets may increase the proportion of fine particles in one batch of pellets. Heating can provide the conditions for smooth operation by proper design of supply pipes to silos or warehouses pellets.

If the proportion of fine particles in a series of pellets is too large, it can lead to failure of screw conveyor and have negative effect on combustion and heating emission behavior on pellets. Leading pellets retailers sieved small particles caused by friction at the final place of unloading before delivery to customers.

![Picture 4. Wood pellets](image)
On the market, there are available two types of pellet heating:

- **Pellet stoves** - designed for placement in the living room. They mainly serve for heating of individual rooms and heating houses with low consumption of energy;
- **Central heating systems** - implemented into boiler room of the building and are used for heating of the entire building and for hot water.

Wood pellets can be stored in a dry cellar. The pellet is supplied automatically or via a worm dosing unit or suction device. Compared with wood chips, pellets occupy only a quarter of the normal storage space so regular detached house has plenty of room for the annual supply of pellets.

Relevant standards:

- **EN 14961-1:2010**: Solid biofuels – Fuel specification and classes.
  Part 1: General requirements
  Part 2: Wood pellets for non-industrial use

### 2.1.2. Wood chips

Wood chips are produced by shredding round wood, whole trees, brushwood with sharp tool in quite correctly (similar) forms and the limited differences in dimensions, mostly long 5-50 mm. Dimensions can be changed by adjusting the blade grinder. The ratio of the volume occupied by the fuel and cavity between is for round wood chips from 0.35 to 0.45 (35-45 % total volume occupied by the wood, and the rest to 100 % are air-filled cavities 55-65 % volume), while the same factor for chips from whole trees is 0.4-0.5. Recent heating systems usually use pellets and wood chips. Automatic combustion in furnaces and boilers puts pellets and wood chips in the same rank with the fuel oil and gas. Furnaces can be turned on and off, achieve and maintain the given temperature and have automatic dosage which gives wood chips advantage compared to wood or briquettes heating. The advantage of wood chips over the pellets is that they are cheaper and in theoretical way energy more efficient fuel since less energy is required for their production.

![Picture 5. Wood chips](image-url)
The only drawback is the low energy density. Since they are stored in a bulk, they use twice as much space than wood logs. Wood chip heating systems are ideally used for average annual fuel consumption of petroleum-based on 4 000 l. Typical applications areas for wood chip plant are agricultural and wood companies (heating of greenhouses), trading houses, apartment buildings, public buildings and micro- and local heating systems.

Relevant standards:

  Part 1: General requirements
  Part 4: Wood chips for non-industrial use

2.1.3. Firewood (logs)

The logs are short pieces of wood of a certain length and shape suitable for combustion in furnaces. Lengths vary and are 0.25 m (for ovens), 0.33 m (for stoves and fireplaces), 0.5 m (for open fireplaces and pizza places) and 1 m (for sale). The diameters of the logs over 35 cm (equivalent to 14 inches) are split for better drying. Usually, boiler is filled manually and this is his biggest drawback. The biggest advantage of the boiler in addition to low fuel costs is effective level of operation - about 90 %. The amount of energy created by burning 3 kg of wood is equivalent to one liter of fuel oil.

Wood logs are the classic form of the fuel supply from wood biomass. Felled and split forest lumber is a result of forest management. The supply of wood for fuel is typically provided by regional partners and sectors of agriculture and forest management. Firewood differs by type (hard and soft wood) and size of wood. Minced firewood is ready for direct use in the stoves.

Increasing demands regarding comfort in private households slowly eliminate firewood from basement and replaces them with modern, fully automatic wood chips and pellets boilers. However,
since tile stoves are trendy at the moment, there is a flourishing demand for firewood. Hardwood, such as beech, maple, oak, ash and birch, are mainly used for heating in tile stoves. Hardwood creates a lot of cinder, which gives a uniform, continuous heat. With cozy flames and burning almost without sparks it is ideal for tiled stoves, especially those with glass monitoring.

To ensure high quality of firewood it is necessary to have appropriate storage. Firewood prepared for use in the oven reaches the required condition of the wood dried in air - depending on the type of wood and storage conditions - after a year or two of storage. Fuel from wood biomass must be dried in as less time on the water content of up to 20 %, which is needed for perfect combustion. In general, all types of wood can be processed into firewood. Only wood that is very purulent, contaminated or treated with chemicals is not suitable for such processing.

### 2.1.4. Briquettes

Wood briquettes are solid biofuels which are mainly used in small scale, hand-loaded furnaces. Wood briquette production still sticks to the idea of a cascade supply chain, using mainly by-products from the wood processing industry, namely saw dust which still has to be dried before further processing, and wood shavings, which can be compressed directly. After cooling wood briquettes are packed in about 10 kg packages and are traded and sold through first traders and then retailers to the end consumers.

Briquetting is a process of material densification briquetting machines in the piston or screw embodiment, a mechanical or hydraulic drive, whereby the material is pressed into a circular cylinder with a diameter from 20 to 120 mm and length 400 mm. Briquettes may be produced only from pure wood and bark. It is unacceptable that they contain glue and/or artificial materials, lacquers and other surface protection products. For briquettes there are a set of technical requirements as to the minimum density and wetness, ash content, nitrogen, chlorine etc.

![Image of Briquettes](source: www.ogrev-briketi.com)
2.2. Biomass heating systems

Very often during planning and project development, the dilemma to build a heating plant or a cogeneration system (CHP) occurs? Both technological concepts have their advantages, disadvantages and challenges. Generally, the plant represents a smaller investment, it is easier to implement and maintain and do not require special licenses for carrying out energy activities, long procedure of obtaining the status of eligible energy supplier and similar. Cogeneration allows higher efficiency use of biomass that is available and significant income from the sale of electricity for which there are available preferential purchase prices.

For the correct answer to this question it is necessary to consider the following circumstances:

- How much heat energy can be used (size of heat consumption)? Ratio of produced electricity and heat varies from 1:3 to 1:5. In case when the heat cannot be spend or financially evaluated, it makes little sense to invest in a cogeneration plant.
- Are there organizational and personnel requirements to conduct complex technical systems such as cogeneration power plant? This question can also solve some of the models of public-private partnerships or concession given that in cities and municipalities it is hard to expect the necessary organizational and human resources will be provided.
- Is there a possibility to assure financial resources needed for a substantially greater investment in CHP plant?

If there is a possibility to give a positive answer to all three questions, it is possible and reasonable to think of a biomass cogeneration as a component of a district heating system.

The cost of heat production from biomass in district heating plants varies depending on the size of the plant and fuel costs. In Croatia the production costs of heat from pellet boilers, size 5-100 kW amounts of 8 to 99 Euro/GJ, with an average of 26 Euro/GJ\(^1\), which makes them competitive in relation to fossil fuels. By 2030, it is expected that costs will be reduced by 4-6 % (along with constant fuel price) due to increased equipment life and efficiency of the system. For district heating, as a fuel are more commonly used wood chips instead of pellets, resulting in higher investment costs, but also lower fuel costs. In Italy a common tariff of the thermic KWh in district heating systems is about 0.11 Euro KWh plus V.A.T. (10 % or 22 % depending on the final user).

\(^1\) Equivalent to 0.0936 Euro/KWh
The economic feasibility of biomass heating plants in district heating system depends on a number of complex techno-economic parameters. The cost of building heating network amounts to about 35-55% of the total investment cost of the system. It is important that this plant has more working hours per year (> 75 %) and that consumers are placed as close to the plant as possible. It turns out that these requirements are relatively difficult to meet because the energy is not constant throughout the year. Also, it is necessary to find the optimal point of investment, taking into account the high cost of thermal insulation networks on the one hand and costs due to heat losses from the other side. Although a large district heating systems can be economically viable, there is large number of economically unprofitable systems because of inadequate optimization between these two costs.

2.3. Biomass Logistic and Trade Centres

Biomass trade centres (BL&TC) are regional service stations for premium quality biomass fuel run by a group of local forest owners and/or forest entrepreneurs. Placement of fuel through BL&TC creates added value for both forest owners and clients who benefit from the supply of high-quality, local biomass fuels. Production range is further enhanced by a comprehensive service, such as fuel delivery or providing competent advice on all questions relating to the proper use of biomass fuels. Through a network of BL&TC, clients can be assured that their long-term supplies for their heating systems are secured. For this reason, private households and businesses can choose this cost-effective and environmentally-friendly heating system in good conscience. Among already mentioned added value, BL&TC also contributes to a crucial boost of the creation of numerous new green jobs and the long term securing of existing jobs in up- and downstream sectors.

The BL&TC concept consists in the construction of a collective rural marketing channel for wood fuels and energy services throughout the European Union countries. Biomass centres will market all kinds of biomass fuels supplied by farmers. The main products are wood fuels (split logs and chips) but also there is a possibility to supplement this by trading wood pellets. Other biomass fuels (whole plant pellets or grass pellets) could also be incorporated into the range of selling products. In addition, it is
intended that these regional biomass centres should also act as energy service providers wherever possible and become involved in wood energy contracting projects and biomass heating plants.

Main advantages of BL&TC implementation from the provider point of view:

- Setting up regional supply centres (BL&TC) in the EU countries offering different kind of wood fuels and energy services;
- Marketing under a standardised word/image mark;
- Safeguarding the security of supply;
- Obvious, visible presentation as a provider of biomass of all kinds;
- Guaranteeing consistent quality standards;
- Promotion of services such as fuel delivery and involvement in wood energy contracting projects.

No matter where they are purchasing fuel from, a biomass centre has the following advantages for costumers:

- Easy and convenient buying (customer-friendly opening times, ordering service etc.);
- Security of supply (continuous supply, available all year round, crisis-proof etc.);
- Local quality provides security when buying (guaranteed quality standards, clear product distinction to foreign wood etc.);
- Price stability and transparency (cost-efficient fuel, transparent prices etc.).

3. Implementation guide

3.1. Initial assessment - HOW to plan biomass district heating project?

To plan, initiate and successfully complete the project of biomass district heating is not easy. Realization of project activities is associated with resource use and risk and requires good organization and cooperation of the coordinator (usually city or municipal administration) and all involved stakeholders. Key elements of the project are:

- Resources - human, material resources and equipment;
- Time - planned to complete the project;
- Financial assets - available for the project.

Typical implementation stages of biomass projects can be divided into:

- Project launching;
- Project implementation;
- Completion of the project;
- Project planning and elaboration;
- Monitoring and control;
- Monitoring the effects and results of the project.
After starting the project, careful planning is the key to ultimate success, but also is detailed definition of all steps and activities of the project. The main task of this phase is to plan time, cost and resources to determine the needed work, hiring experts and reduce the risk of the project. When it comes to projects initiated and implemented by cities and municipalities, this is the prime time to ask some important questions:

- Is the biomass district heating project really a top priority for the community?
- Do citizens support the project and do they intend to become beneficiaries of the heating system?
- Is the necessary heat consumption secured by connecting public buildings (schools, hospitals, kindergartens, administrative buildings, etc.), or whether it is necessary to involve the wider community as well as consumers?
- Can a safe and reliable supply of biomass at affordable prices be provided? Can long-term contracts be concluded?
- Who will be responsible for the operation and maintenance of power plants?
- Are the funds from the budget sufficient, or it is necessary to find other sources of financing?
- Is the human capacity and knowledge to plan and implement the project within the city or municipality sufficient?
- How sure is getting a grant? - risk assessment.

After conducting preliminary analysis authority of the city or municipality decides to launch the project. Following the decision on launching the next phase of the project can be divided into:

- Informing project stakeholders (citizens, business owners, forest owners, media);
- Conducting a public procurement procedure for selection of the designer;
- (Optional) Application of the project documentation for the available grants;
- Planning and elaboration of the project (preliminary, main and executive project);
- Permits for the works (building permit, a study on the environmental impact, etc.);
- Contracting woodchip supply from the local forest owners;
- Optional if its own budget funds are not sufficient for implementation:
• Proposal for grant (structural funds);
• The implementation of the public procurement procedure at PRAGUE (in the case of a grant from the Structural Funds);
• Contracting of works, supervision and other sources of financing;
• Monitoring and control;
• Register (new) utility company or open company for the management of district heating plant;
• Completion of the project;
• Monitoring the effects and results of the project, informing project stakeholders (citizens, business owners, forest owners and media).

Errors and omissions in the planning significantly reduce the chances of successful project implementation which can successfully be avoided by conducting following activities:

• Determine the level of planning and detail what is planned;
• The establishment of the planning team;
• Identification of objectives to be achieved and activities that will allow it;
• The assessment of available funding;
• Estimation of the time and cost of all activities;
• Creating a schedule of activities;
• Creating a project budget;
• Planning the risk of project implementation;
• Connect and informing citizens in the planning and implementation process;
• Gaining formal permission to start work.

3.2. Detailed feasibility and project documentation

Project documentation is a broad term that encompasses everything necessary for project design and development, as well as providing all required permits. The complete, transparent and well-prepared project documentation is an essential part of every project. This is an important, but often neglected or underestimated part of project preparation and implementation, for which is essential to separate the adequate amount of time and resources.

A biomass district heating project consists of a biomass heating plant with fuel tank and heat network that extends from the heating plant to the energy consumers. Construction activities included in the project must be corroborated by a specific documentation, which for example in Croatia consists of the following recordings:

Conceptual design

• An important initial document, the basis for a main project;
• Selection of best varieties that are checked during their preparation;
• Choosing the best solution;
• Includes basic principles solutions for specific engineering disciplines;
• Contents: Introduction, description of technical solutions, expenses, financial resources, the pace of project implementation, the expected effects, calculate the emission reduction of CO₂, SO₂ and NOₓ, miscellaneous (maps, photographs, leaflets etc.).

Conceptual design should provide sufficient information to start preparing an investment study which is the main basis for deciding on the financial value of the project.

**Investment Study**

• Also known under the name investment program or feasibility study;
• It is necessary for larger projects to obtain bank loans, grants, certain EU funds or incentives of individual ministries - the most important results are the calculation of the expected profitability of the project through a series of static and dynamic project parameters and financial statements;
• In the case of the biomass heating plants it is necessary to include, beside the cost of the investment, the correct initial assumptions about the price of biomass, plant operating costs and selling price of heat energy;
• If investment study shows that the project is justified, further steps can be undertaken.

**Main project design**

• A set of coordinated projects which provide a technical solution and demonstrate the fulfilment of the essential requirements for the building, as well as other requirements and specific rules and technical specifications;
• It cannot, in terms of location conditions, be in conflict with the conceptual design;
• The Public Administration in charge (Ministry or Local Authority) issues a certificate of the main project or a building permit;
• The investor is obliged to permanently preserve a building permit or certificate of the main project;
• Depending on the type of construction it includes: architectural design, construction design, electrical engineering project, engineering project and projected cost estimation of the work;
• It can also include technical solution (for buildings covered by the obligation of determining integrated environmental protection pursuant to special regulations), geodetic project, a foundation project, landscape design, geotechnical design (for buildings that require evidence of mechanical resistance and stability);
• The project must include data from elaborate that served as a base for its development and the design life of the building and the conditions for its maintenance.

**As built design**

• Development of technical solutions established by main project;
• It must be made in accordance with the main project;
• It is a foundation for construction itself;
• The investor is obliged to store it as long as the building exists.

After the preparation of the necessary documentation the public procurement for equipment and work is required as well as obtaining permits such as construction permit explained hereafter.
Construction permit

- A request for the issuance must be submitted by the client;
- The request shall be accompanied by:
  - evidence of the right to build on a certain property,
  - construction project in four copies with confirmation that it was made in accordance with the specific conditions,
  - a written report of the main project,
  - validity confirmation,
  - a list of parties.

- A building permit is a document based on which one can begin construction of the building. It establishes that the main or preliminary design is in line with the regulations and conditions to be met by building in a particular location and that they met the entire necessary postulate for building.

Building permits are issued by the Local Authority office in charge of construction in the area where building is built, if the Building Act or some other special acts tell otherwise. Ministry of Environment and Physical Planning issues building permits for buildings and traffic, power plants, water structures, industrial structures, waste management and buildings for special purposes.

![Building with chimney](image)

*Picture 10.* The building with the chimney of the central biomass heating plant in Gospić (Croatia)

### 3.3. Procurement and implementation - Technology and how to choose the best option

Biomass is in many ways unique renewable energy source. It can be easily stored and transported, unlike other renewable energy options such as wind and solar energy where electricity production work intermittently and produced electricity needs to be immediately spent as well as have a connection to the network. With the exception of scrap and waste, biomass costs often represent a
significant share of the cost of bioenergy production, usually 50-90%. This fact makes the economics of biomass completely different from other free renewable energy sources (wind, solar, geothermal wave, etc.).

Biomass heat production is a traditional way of utilizing biomass and for this type of energy conversion there are a number of different technologies. For small and medium district heating systems (200 kW to 20 MW) are most commonly used grate boilers because of eligible investment and maintenance costs. Technology with a moving grate boiler (in production since the 1970s) has a better thermal efficiency and emission reduction (CO, NOx) from the technology with a fixed grid (due to better combustion control). Technology with a moving grid is also better because multiple types of biomass can be used and the moisture content in the biomass can be higher. On the other hand, the technology has higher capital and maintenance costs and profitability depends on the size economy - only larger plants (> 20-30 MW) are economically viable. Until now, a total number of installed facilities in the world is over 300.

Biomass heating systems are commercial and competitive, although this conclusion largely depends on the movement of fossil fuels prices. Even though the technology is already proven, the economics of biomass district heating depends on a number of complex techno-economic parameters. In some countries, biomass district heating has a significant share in the satisfaction of the total heat demand (northern Europe countries). Although district heating with a suitably dimensioned network can be economically justified, the high cost of network expansion and inability to guarantee the overall high efficiency are the main problems that prevent their further development. However, the growing interest in district cooling, especially in combination with the production of heat and electricity (trigeneration), is improving economic justification of biomass plants and supporting infrastructure.

Research and development of these systems in the future are focused on increasing the thermal efficiency and development of smaller systems that use different types of biomass (crops, trees remains, etc.). Since combustion generates significant quantities of toxic compounds (especially NOx) and ash, the development aims to reduce emissions to air and discharge of ash in order to meet increasingly stringent policies and regulations in this context. These solutions are especially important for small district heating systems, as it is necessary for them to develop a simple and economically affordable solution.

Regarding economic indicators, electricity plants and cogeneration do not depend only on the current technology (capital and operating costs, conversion coefficient, reliability, etc.), but the crucial are biomass supply (quality, type, availability and price) and consumer energy needs (cost of production of alternative energy, thermal requirements, network availability, legal aid, etc.). Wide range of prices related to the technology, points the importance of economies of scale (e.g. for steam turbines), but also that the majority of technology is still in the early stage of development (Stirling engine, BIG / CC, organic Rankine process).

As an alternative to conventional steam systems (0.5-2 MW) steam turbine with organic Rankine cycle (ORC steam turbine) is used which has significant technical and economic advantages (e.g. lower temperature process, lower maintenance costs and the possibility of installing the boiler on liquid fuel instead more expensive high-temperature gas boiler). Although ORC is proven technology (e.g. in systems that use geothermal energy), there are currently only a small number of ORC
biomass systems (Switzerland, Austria and Netherlands). It is necessary to increase the efficiency and reliability and reduce the cost of these systems.

For systems with less power (10-100 kWe), Stirling engine represents a promising technology. It is currently in the testing phase (in Denmark, Germany, Great Britain, Switzerland, Austria and New Zealand) and some improvements are needed. In particular to increase the existing efficiency from 12-20 % to 28 % and develop systems with higher power (150 kWe). For the fuel for this technology biomass is little used, although there are some attempts in Germany where the pellets are used as fuel.

3.4. Operation and maintenance

In order to determine the optimal dimensions of the heating system and successfully regulate the sale of heat, it is important to conduct a market analysis which determines the potential buyers and the related consumption. Market sales analysis is conducted through survey in which consumers can express their interest for connection to the district heating system. The cost of connecting relating to the installation of thermal stations with built calorimeter is borne by the consumer in the form of one-time cost or charges for a higher tariff class for a certain period. Relations between supplier and buyer of thermal energy are governed by the contract.

The charge for heat includes a fixed amount regardless of the overall consumption relating to leased power and a variable amount of the consumed thermal energy. The representative body of a local government in determining tariffs has the ability to adjust tariffs to customers – e.g. tariffs for citizens and tariffs for business customers.

One of the key issues for the quality work of power plants is certainly a question of biomass supply since the selection of the boiler is based precisely on the type of fuels. Biomass supply contracts are signed to multi-year period (at least two or three years) and it is important to identify items related to:

- Characteristics of biomass - origins, dimensions and the amount of moisture must be adapted to the system to ensure proper operation of the boiler. Performance testing is done on delivery of biomass;
- The cost of biomass – the features of delivered biomass are in direct correlation with the price. The measured higher amounts of moisture will result in a lower purchase price;
- The dynamics of delivery and payment terms - the security and continuity of supply of biomass are essential. Due to seasonal fluctuations in demand, the amount of delivered biomass is defined on a monthly basis. Inventories of biomass must be sufficient for a number of days to ensure smooth operation of the drive - usually a month;
- Punitive measures - for each deviation and any omission by biomass supplier penal provisions must be provided to ensure the smooth operation of power plants. If the supplier does not deliver biomass feedstock on time, it is necessary to ensure the alternative suppliers, but the difference in price must be compensate by the first supplier.
Due to the automation of the heating facility, staff does not have to possess specific technical qualifications for the management and servicing of heating, assuming that they are trained by the equipment supplier. Biomass boilers typically require low maintenance (e.g. removing dust from the sensor and removing blockages from the supply system). Thus, the presence of personnel is not required during normal operation power plants, but during the fuel takeover the presence of workers is essential for checking the prescribed quality, humidity and dimensions of chips. If the size or price of biomass do not meet the required characteristics it is desirable to consider the purchase of stationary stump.

If a fault occurs in the work of the boiler, the system automatically sends SMS notification to authorized persons. To ensure timely removal failure and minimize the downtime of the system it is important to determine the contract deadline by which servicer is obligated to cure the defects. On-call service is very important in winter conditions, so for example in Austria the deadline for the arrival of the maintenance technicians and the elimination of failure is three hours.

![Biomass system for office heating (220 kW), North-West Croatia](image)

**Picture 11.** Biomass system for office heating (220 kW), North-West Croatia
Regional Energy Agency premises in Karlovac County (Croatia)

### 3.5. Monitoring of the project implementation

Monitoring and supervision of the project implementation are very important components of the biomass district heating project from the preparation of project documentation until the realization of the project through the construction of the building boiler room, storage building for biomass storage and infrastructure networks for the heat distribution.

During the preparation of project documentation the role of supervision is done by the consultant of the project. Consultant may be local energy agency or another consultation body whose professional capacity is equal or greater than designers. The importance of project documentation control lies in the fact that designers do not typically deal with the economics of the project. In the sense that if
there is a real need for a boiler of 100 kW, often, for safety reasons, 150 kW is designed which immediately results with higher investment costs and other system components, such as building plants.

For the realization of the project or the construction of the plant, the quality of execution of all phases of work and meeting deadlines is of unquestionable importance. The quality of work performance is reflected in the functionality, safety and durability of the plant and it is ensured by the implementation of work supervision. Conducting surveillance is a legal obligation which is, on behalf of investors, carried out by an authorized supervisory engineer.

Biomass district heating is a complex of buildings so the main supervising engineer must employ appropriate supervisors in order to conduct quality control of certain types of work. Supervisory engineers supervise the construction and execution of the installation through the following activities:

- Day tour of the location of construction and supervision of construction to be in accordance with the decision on building conditions, confirmed by the main project or a building permit;
- Daily inspection and verification of building log and other required documents (e.g. a welding diary, etc.);
- Control the performance of the work;
- Verification of monthly situation;
- Coordination of all activities at the site;
- In case of need to change the design documents or the exchange of work performance due to objective circumstances, the contractor proposes, reviews and approves changes.

These activities ensure deadline compliance of work performance, as well as control and quality assurance work. The public procurement procedure should also serve as a mean of quality assurance of equipment and works and in this sense there is a clear need to set up and define all key criteria that affect the quality, as well as technical parameters of the equipment, materials and other.

4. **Financial tools for the evaluation of the economic feasibility of a biomass heating plant**

The evaluation of the economic performance of a biomass heating plant project can be carried out following strict accounting-financial guidelines that are helpful in supporting management decisions both for private investors and for Public Administrations. In this way the feasibility of the project will be based on explicit economic analysis.

The most useful methods, applied in this context, are:

- The Cash flow and Net Present Costs analysis,
- The Internal Rate of Return (IRR) analysis,
- The Pay-back period (PBP) calculation,
- The Price of break even point (Pbep) calculation.
4.1. Cash flow and Net Present Costs

Investing in a heating system powered with renewable resources, means investing capital available today, giving up its consumption, in view of a possibility of having more capital to be allocated to the consume at a future time \( t \). This means investing a capital today in view of a possible reduction of future operating costs of a thermal plant.

To assess the convenience or not to make this investment the Net Present Value (NPV) is a very meaningful assessment tool. The Net Present Value is a method by which you define the present value of a series of expected cash flows, not just adding them in the accounts, but discounting them on the basis of the rate of return (opportunity cost of equity).

Cash flow is the reconstruction of the difference between the revenue and outflows of a business over the period of analysis. In our specific case (the installation of a biomass heating system), the business is a pure flow of investment and management costs and therefore it is more advisable to speak of Net Present Costs (NPC) method than of NPV method:

\[
NPC = \sum_{t=0}^{n} \frac{C_t}{(1 + r)^t}
\]

where “\( n \)” is the time of the investment, “\( C_t \)” the total yearly costs incurred in year \( t \)-th and “\( r \)” is the rate of interest, or discount rate.

Generally the duration of the investment is conservatively assumed to be equal to fifteen years, knowing that, on the basis of the existing literature, the average life of thermal plants fueled by wood chips can easily exceed 20 years, but it is necessary to evaluate also the instability of the fuel prices. In the evaluations of the investment feasibility of the new thermal plants, the costs incurred at year 0 are represented by the total cost of installation (in summary: boiler and other components, building of the boiler plant room and of the woodfuel store, building of the network of underground heat main, engineering services and possible installation of a backup boiler). While from year 1 to year “\( n \)” (generally equal to 15), are considered the sums of the annual operating costs (ordinary and extraordinary maintenance, purchase of wood chips, expenses for electricity and interests for the anticipation capital).

The method consists of:

1. defining the cost flows for the biomass district heating plant,
2. reporting the cost flows for the fossil district heating plant,
3. discounting the two cost flows: Net Present Cost biomass-fired (NPCR) and Net Present Cost fossil fuel-fired (NPCF) [23],
4. Comparing the two NPCs.

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2 For example in Italy, the rate of interest can be considered equal to 4.4% with reference to the fixed rate currently applied by the Deposits and Loans Agency for investments with a duration of about fifteen years.
The economic performance indicator is:

the difference between the two NPCs (\(\Delta NPC\)).

The equation is:

\[
\Delta NPC = NPC^R - NPC^F = \sum_{t=0}^{n} \frac{C_t^R}{(1 + r)^t} - \sum_{t=0}^{n} \frac{C_t^F}{(1 + r)^t}
\]

where:

\(C_t^R\) = total annual costs borne at year \(n\)-th for the biomass-fired plant (R),

\(C_t^F\) = total annual costs borne at year \(n\)-th for the diesel-fired plant (F),

\(n\) = duration of the investment,

\(r\) = interest rate, or discount rate.

### 4.2. Internal Rate of Return (IRR)

The Internal Rate of Return (IRR) is a rate of return used to measure and compare the profitability of different investments (e.g. IRR as compared to the mortgage loan interest rate, or to the interest rate of alternative investments).

The IRR is based on an inverse logic compared to the NPV. In this case, in fact, given a sequence of expected cash flows discounted to present value, it is set equal to zero their sum, where the IRR is the discount rate that equalizes the expression.

Therefore, the IRR is the rate that makes equal to zero the formula of the NPV.

In our case IRR is the discount rate that makes zero difference of the discounted costs of the two investments, i.e. that makes zero the \(\Delta NPC\).

What is the meaning of this index? It represents the maximum cost of capital, without compromising the cost-effectiveness of the investment. The investment has, in fact, economic convenience until its annual return (in %), is greater than its relative cost.

How then can be analyzed the IRR? There are three possible interpretations in relation to who is the holder of the capital:

(1) In case the investment is financed with a loan: then, for the investment to be profitable, the IRR must necessarily be higher than the rate that is applied to me by the finance company; thus the cost of invested capital will be lower than the savings achieved with the replacement of the old heating plant with the new one powered by wood fuel;
(2) similarly, IRR is also the maximum cost of capital, which is the maximum rate applicable from the finance company, which guarantees me a cost-effectiveness of the investment;

(3) if no use is made to a loan, but I’m using my own capital, the assessment is based on a choice between two alternative investments: then, even in this case it will be needed that the IRR is higher than the annual return that this capital guaranteed me originally.

In conclusion, the greater the IRR and the greater is the annual yield offered by the investment.

4.3. Pay-back period (PBP)

The pay-back period (PBP) is the number of years required to recover the funds spent in the investment on biomass heating system.

It is a widely used indicator to assess the suitability of an investment. The concept of PBP is simple and intuitive; it answers the question: how soon will I recover the initial investment?

The PBP, in fact, is nothing more than the number of periods (years) necessary to ensure that net cash flows accumulated system is equal to the initial investment. Formally, in its simplest version, Pay-Back Period (PBP) is given by:

\[
PBP_{\text{(years)}} = \frac{C_0}{(R_{ay} - C_{ay})}
\]

Where:

\begin{align*}
PBP & = \text{Pay Back Period} \\
C_0 & = \text{initial investment} \\
R_{ay} & = \text{average yearly revenues} \\
C_{ay} & = \text{average yearly costs}
\end{align*}

In our case, the initial investment \( C_0 \) is represented by the overruns that are necessary for the installation of a biomass thermal plant, instead of a plant fed with fossil fuel; while, the net cash flows that occur every year \( (R_{ay} - C_{ay}) \), are represented by the net savings that you can have on the operating costs, thanks to the introduction of a plant fueled with wood biomass.

Usually, each investor sets a time limit (cut-off period) within which the investment must be recovered. The PBP, allows him to figure out if it’s worth investing in this sector.

The defects of this indicator are essentially attributable to the fact that it does not consider the flows achieved in the period subsequent to the PBP and the fact that it does not consider the amount of capital invested.

The PBP has however the advantage to be calculated with relative ease, and can be easily interpreted by non-experts.
4.4. Price of break-even point (Pbep)

The Price of Break Even Point (Pbep) for wood chips (or other wood biomass) is the maximum price that the heating plant managers (the consumers) are able to pay to the harvesting enterprises (the producers) and that covers the total production costs.

In our case the estimate of the Pbep of biomass (wood chips) is represented by the price of biomass which allows to match the flow of discounted annual costs derived from the investment in thermal plants fueled with biomass (wood chips) with the flow of the annual costs discounted derived from investment in thermal plants fueled by fossil fuels (oil or gas), considering a given discount rate. In other words the Pbep of biomass is that price which allows equal the Net Present Cost of the renewable energy plant (NPC\(^R\)) with the Net Present Cost of the fossil fuel plant (NPC\(^F\)).

\[
\Delta NPC(P) = NPC(P)^R - NPC^F = 0
\]

Where “\(p\)” is the price of wood biomass (wood chips).

It follows that Pbep corresponds to the maximum price of wood fuel, which the user can support while ensuring the economic viability of the investment in the period (15 years) considered.

The analysis of the Pbep allows also checking the viability of the wood biomass supply chain. In fact, if the unit production costs (€/t) of wood biomass (wood chips) exceed the Pbep of the consumer (the manager of the heating plant), it means that there is no economic basis to ensure the economic sustainability of the supply chain. This is because the biomass producer is not able to sell the chips at a price below the maximum sustainable by the consumer (consumer Break Even Point). Conversely, if the costs of production per unit of the biomass producer are much lower than the consumer’s BEP, this means that there are large margins of safety and cost effectiveness for both the producer and the consumer and that the chain is economically viable. Forest entrepreneur can then invest in the new area because there are a large number of users (consumers) are willing to buy the wood chips to the current market prices with large safety margins on consumer prices.
References

Various authors (2012), *How to develop and implement biomass district heating projects*, North-West Croatia Regional Energy Agency, Zagreb, Croatia


Various authors (2009), *Energy crops in arable lands*, AIEL – Italian Agri-forestry Energy Association, Italy

Various authors (2012), *Handbook on biomass fuels*, North-West Croatia Regional Energy Agency, Zagreb, Croatia


Various authors (2012), *Catalogue of forest biomass producers in Croatia*, North-West Croatia Regional Energy Agency, Zagreb, Croatia


Loibnegger T., Metschina C. (2012), *Biomass logistic and trade centres- 3 steps for successful project implementation*, North-West Croatia Regional Energy Agency, Zagreb, Croatia

IEA Bioenergy (2007), *Potential contribution of bioenergy to the world’s future energy demand*, IEA Bioenergy

IEA Bioenergy (2007), *Bioenergy in our community*, IEA Bioenergy

Loibnegger T., Metschina C., Gaber M. (2012), *Quality fuel for everyone*, North-West Croatia Regional Energy Agency, Zagreb, Croatia


Maras M., Domac J. (2012), *Information brochure on renewable energy sources promotion for citizens, small and medium enterprises and craftworks*, City of Zagreb, Zagreb, Croatia

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