LEBANESE REPUBLIC
MINISTRY OF ENERGY AND WATER

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BIOMASS PELLET BOILERS

A Guideline Report for Practitioners

Editorial
This document should be referenced as:
Sustainable Energy for security.

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Disclaimer

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Sustainable Energy For Security

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LIST OF ACRONYMS

AFNOR	Association Francaise de Normalisation
BCS	Biomass Combustion Systems
CO_2	Carbon Dioxide
Cp	Specific Heat
CTE	Technical Building Code
DHW	Domestic Hot Water
ΔT	Temparture difference
EU	European Union
ISO	International Organization for Standardization
Kcal	kilocalorie
kW	kilo-watt
LAF	Lebanese Armed Forces
LPG	Liquified Petroleum Gas
m	flow rate
MPa	Mega Pascal
MWh	Mega Watt-hour
NDC	Nationally Determined Contribution
Pot	power of the boiler
SE4S	Sustainable Energy for Security
t	tonne
TOE	Tonne of Oil Equivalent
UNDP	United Nations Development Programme

01 INTRODUCTION

1.1. The Project

The European Union funded, United Nations Development Program (UNDP) implemented, “Sustainable Energy for Security” (SE4S) project focuses on strengthening the security and well-being of the Lebanese Armed Forces (LAF), specifically the LAF stationed in the North-Eastern border region of Lebanon. The aim of the project is the provision of sustainable energy solutions that, first and foremost, increase the LAF’s energy autonomy in the region and enhance the general energy services that achieve a higher ability to observe and carry out the respective security-based operations.

Additionally, these actions build on the Lebanese Armed Forces Sustainable Energy Strategy of 2017 (EU-UNDP CEDRO 4, 2017), endorsed by the Lebanese Ministry of Defense and the LAF.

• The LAF Sustainable Energy Strategy endorses Lebanon’s Nationally Determined Contribution (NDC) commitment under the Paris Climate Change Agreement of 2015, and commits the LAF built environment to the following targets to be reached by 2030:

· 20% of its total electricity consumption is to be generated from renewable energy sources
· 20% of its total thermal consumption is to be generated from renewable energy sources
· 10% reduction in energy use per square meters.

1.2. Guideline Report

This guide focuses on a practical approach to planning, acquiring and operating a biomass combustion system (BCS). It outlines the considerations a buyer should make before engaging the professional services of experts in the field.

The report describes the different possibilities and choices to be made, highlighting, when necessary, details of a specific project implemented.

1.3. Demand analysis

Modern biomass heating systems are equipped with automatic feeding and extraction devices. Currently, there are many solutions for setting up a biomass heating system. The choice of the type of boiler, fuel supply technology and silo depends on the characteristics of the project:

- the energy needs of the project allow to define the power of the boiler to be installed and the heat transfer fluid (hot water, superheated water, steam);
- the available biomass fuel allows defining the type of furnace (according to its nature, its granulometry type, grain size and humidity), the feeding system and the delivery method.

1.3.1. Energy needs

The determination of the heating needs of a given space or building is critical to avoid under or oversizing the heating system. Key parameters for the determination of the space heating demand profile include:

- Specific climatic conditions,
- Eventual seasonality,
- Indoor (desired) temperature ranges,
- Surface areas and volumes of the spaces to be heated,
- Type of building insulation, and
- Heat transfer losses within the building envelope.

The standard ISO 13790: 2008 "Energy performance of buildings – Calculation of energy use for space heating and cooling" is a typical reference for heating systems engineering. It is advisable to assess potential measures to reduce the heating demands, such as thermal envelope (walls, floors, ceiling/roof) insulation or installing double glazed windows among other measures (details and best practices are provided in "Building Envelope Retrofit: A Guideline Report for Practioners"). Any reduction in the heating demand will allow the use of smaller (and cheaper) boilers, as well as a reduction in fuel demand.

A building's thermal energy needs are a combination of hot water provision and thermal comfort provided for from a common budget.

The estimation of how much heat is required to meet conditioning needs is critical.

Once the heat load is defined and refined, the boiler (or boilers) is sized properly.

In simple terms, the process involves the following steps:

a. List spaces for heating.
b. Estimate the floor area of spaces to be heated.
c. Establish an ideal temperature for the spaces.
d. Use information b and c (plus any information on building heat loss or air changes) to estimate the heat requirement for each space. The results can be used later to aid in specifying radiators.
e. Sum to obtain the total space heating load
f. Sum other load requirements for the property.
g. Sum information e and f which will provide the BASIC HEATING LOAD.
h. Take into account other considerations (i.e. other significant thermal inputs from a solar thermal water collector, expected simultaneity in heat demands or lots of lighting emitting radiant heat, as well as dynamic effects).
i. Subtract value obtained under point g from value gotten under point h to get the IDEAL BOILER CAPACITY.

1.3.1.1. Climate

The geographic location of the facility and its climate conditions will determine the time of use throughout the year for both heating and domestic hot water. In addition, the following points are considered:

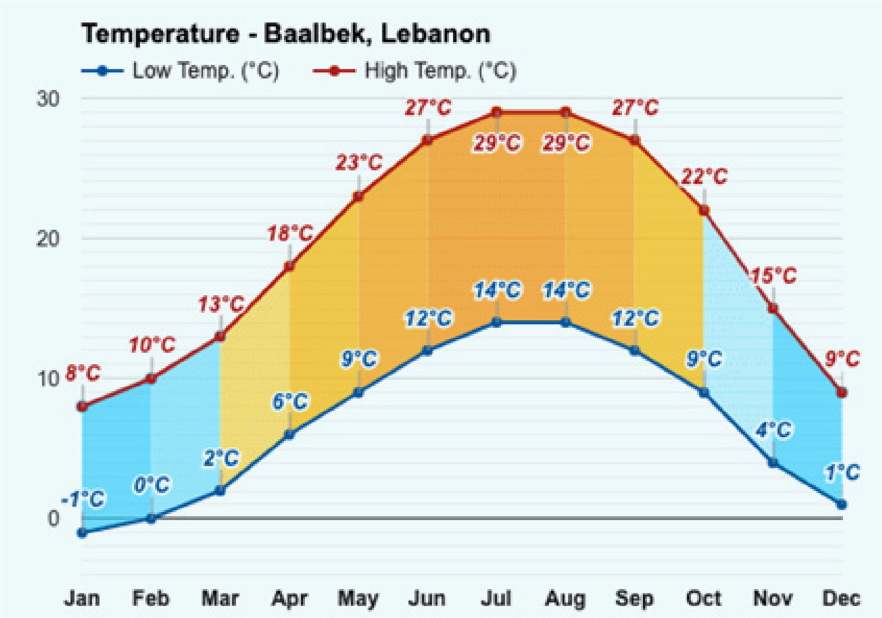
- Historical weather data collected from nearby weather stations.
- Map of annual temperatures and relative humidity in the area.
- Thermal needs focused mainly on the winter period, days of minimum temperatures and critical moments of low temperatures in the coldest months.
- Calculation of annual heating demand days and daily hours of heat supply to the facilities.

Table 1. Example of thermal requirement assessment for facilities located in the Nord-East border of Lebanon and Syria

Figure 1: 2nd Land Border Regiment location

The nearest reliable meteorological station is located in Baalbek.

Figure 2. Temperatures in Baalbeck



Thermal requirements will be mainly focused on the period between October and May, where average temperatures are below 20 ºC, with a clear critical point in the winter months of December, January and February.

Heating need occurs on 200 days with an 8-12 hours daily operation. Whereas, for domestic hot water, the needs are across the entire year, although they will be reduced during the warm season.

1.3.1.2. Buildings Characteristics

The calculation of the heating demand is done carefully to size adequately the boiler power. Some of the building characteristics to be assessed include the location of buildings, orientation, glazed opening area, exterior wall area, the exterior floor area or the area adjacent to the neighbors, roof area adjacent to the neighbors' or not and transmission coefficients. It is recommended to ask a professional installer to perform an accurate calculation of the heating demand.

The heat losses by transmission in walls, windows, floor, ceiling, doors and losses by air infiltration must be determined for each of the rooms that make up the house.

It is important to consider different factors to estimate in a quick and approximate way the heating capacity of a house, including:

• Factor A. Demand, measured in W/m^2. The factor varies depending on the intended room function, the location in the context of the building and the heating system used in the building. For example, living on the second floor is not the same as living on the fifth floor. As a rule of thumb, 100 W/m2 is the assumed average.

• Factor B. Correction coefficient applied based on the outdoor temperature of the building being assessed.

• Factor C. This factor regulates the demand based on the construction year (lifetime of the building being assessed).

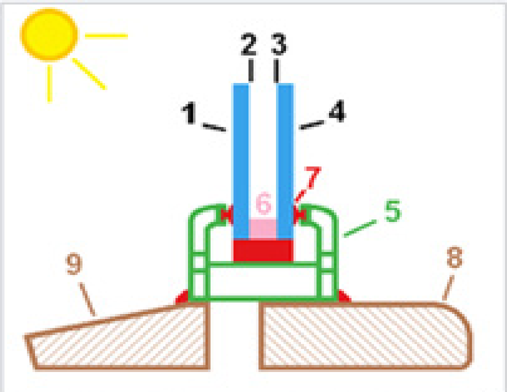
Thus, one of the most efficient methods to calculate the thermal needs of buildings is to multiply the surface of the premises (the room being evaluated) by these three factors that vary depending on the characteristics and location of the building.

Energy consumption in the domestic and tertiary sectors soars during the winter season due to the operation of heating systems. Half of the energy consumed in a home throughout the year is used to provide heat, about 20% is used to produce domestic hot water and the rest is consumed by appliances, cooking and lighting systems.

Considerable energy savings can be achieved through regular up-keep and maintenance of the buildings and adopting some energy efficiency measures, such as:
- Checking the insulation of windows and shutters. A very efficient measure is to install double window systems (or at least double glazing), as they reduce heat loss by almost half compared to single glazing. Ensuring the shutter boxes have no slits and are properly insulated (Figure 3, Figure 4). It is to be noted that thick curtains retain heat.
- Checking the building envelope (walls / floors / ceilings or roofs). A poorly insulated house requires more energy; small improvements to the walls can lead to energy and economic savings of up to 30% in heating.

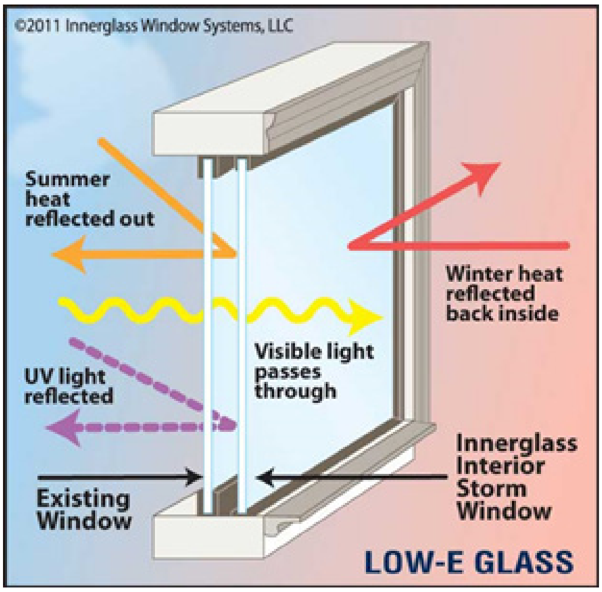
Additional information about measures and retrofits to optimize the building consumption is provided in the "Building Envelope Retrofit: A Guideline Report for Practioners" document.

Figure 3. Double glazing window scheme



A sectioned diagram of a fixed insulating glass unit (IGU), indicating the numbering convention used in this article. Surface #1 is facing outside, surface #2 is the inside surface of the exterior pane, surface #3 is the outside surface of the interior pane, and surface #4 is the inside surface of interior pane. The window frame is labelled #5, a spacer is indicated as #6, seals are shown in red (#7), the internal reveal is on the right hand side (#8) and the exterior windowsill on the left (#9)

Figure 4. Double window scheme



Although comfort is subjective, it can be assumed that a temperature ranging between 19°C and 21°C is defined as 'comfort temperature' during the daytime. At night, comfort temperature ranges between 15°C and 17°C. For every degree increase in the temperature, energy consumption increases by approximately 7%. Therefore, temperature setpoints can have a considerable impact on the building's thermal demand.

For boiler systems and hot water radiators, maintaining the desired temperature in each room is achieved through the installation of thermostatic valves on the radiators themselves.

There are also centralized control and regulation systems on the market, known as domotic systems or building automation solutions. These systems make it possible to differentiate between different zones in the house, record and give a warning signal in the event of faults and also integrate security functions against theft, comfort and equipment operation, even remotely.

It is advisable to turn off the heating at night, except in very cold areas, and to adopt the internal migration concept which used sunny spaces when the sun is available in cold seasons. Hence lowering the temperature or even turning off the heating system in unused spaces.

When away for a few hours, it is recommended to reduce the thermostat setting to 15°C (the "economy" setting on some models corresponds to this temperature), and in cases of longer absences (i.e. for a few days) then heating systems should be turned off.
Ventilation of a complete room is achieved by opening windows for up to 10 minutes; sufficient time to renew the air beyond which energy is wasted.

Heating equipment requires yearly servicing, commonly at the beginning of the heating season, to ensure optimal performance and efficiency of the systems (i.e. for gas or diesel boilers through cleaning of residues and for radiators through the removal of air). Proper maintenance saves up to 15% of energy consumed.

It is highly recommended not to cover or obstruct the radiators to optimize the utilization of the emitted heat. If radiators are installed in recesses or niches, it is important to place reflective elements behind them.

Consideration should be given to the below notes, especially when designing/sizing a heating system:

- Heat in the indoor spaces flows from the warm rooms to the cooler rooms, and from the bottom to the top.

- On average, in a poorly insulated house, heat losses are distributed as follows: walls (35%), ceiling (25%), floor (15%) and doors and windows (25%) .

1.3.2. Current heating system data

1.3.2.1. Description of the system

A brief description of the heating system and construction data is provided. Minimum requirements include:

- Type of building to be heated, year of construction and degree of insulation of the building.
- Current heating system, if any, fuel and annual consumption data.
- Domestic hot water system for winter and summer, including type of storage tanks, storage capacity and fuel used.

Table 2 showcases a practical example of how to calculate the power of a biomass boiler and the quantity of pellets needed.

Table 2. Example for sizing a biomass boiler.

Sizing a boiler system for a single family house in SPAIN:
Useful surface to be heated: 120 m^2
Maximum capacity of the house: 4 people
Equipment considered: Pellet stoves and pellet boilers
To calculate the power required for the boiler or stove, the heating and domestic hot water thermal needs should be determined.

Using the rule of thumb, heating thermal needs are assumed to be 100 W/m^2. To obtain an accurate value, an in-depth study is required, including an assessment of the building's insulation, the number of windows, the location, etc. However, current pellet boilers and pellet stoves work very well at both low and high loads. Therefore, the heating thermal need for this example is 12 kW.

DHW thermal needs are calculated using the maximum number of people who can use the DHW simultanously. In the present example, it is 4 people. The CTE (Technical Building Code) specifies the consumption of each person/day to be 30 liters. Therefore, the DHW thermal needs for the working example is 120 liters/day.

The formula below will be used to calculate the boiler capacity to meet the DHW needs identified:
$Pot = m * Cp * (\Delta T)$

Where:
- Pot - is the power of the boiler (kcal/h).
- m - flow rate of water to be heated (kg/h). The density of water is - 1 l/kg.
- Cp - specific heat of water. (1 kcal/kg-°C)
- ΔT - thermal jump of the fluid (°C)

Assuming: 0.5 h to heat the temperature of the mains water from 10 °C to 60 °C,
Pot = 120 kg/ 0.5 h * 1 kcal/kg°C (60°C-10°C) = 12,000 kcal/h.
converting the units to kW:

Pot = 12.000 kcal/h * 1 kWh/860 kcal = 14 kW
Therefore the optimal boiler capacity is 14 kW, since the DHW has higher requirements that the boiler system size in step 1 at the beginning of the working example

1.4.2.2 Fuel consumption data

The consumption history is retrieved and used as a reference value to estimate the pellet storage capacity requirements. As an example, when replacing a diesel system, knowing that the calorific value of diesel is approximately double that of pellets, every 1000 liters of diesel, will be replaced with 2100 kg of pellets to deliver to the building an equivalent power in kW[3].

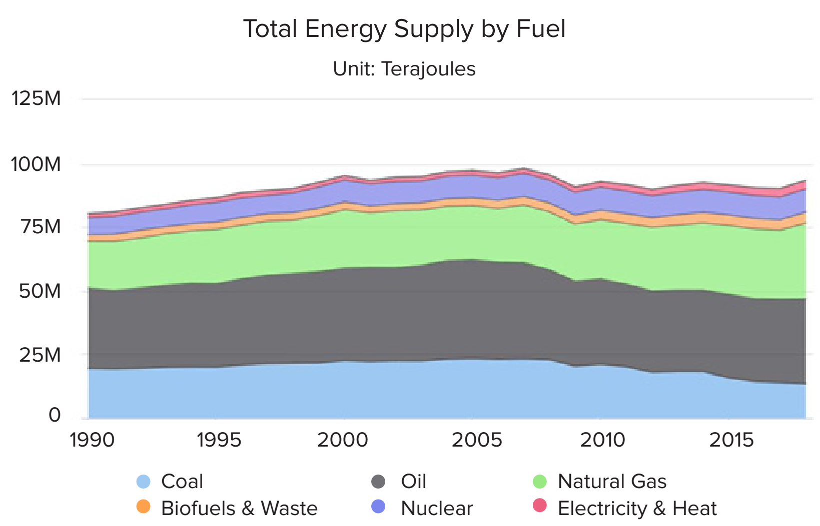
To ensure the pellet supply, one of two options could be applied:

- The purchase or establishment of a production facility, which requires raw material (forest or agricultural residues), machinery and means for the production line with sufficient supply capacity.
- The purchase of the seasonal demand through competitive bidding.

1.4. Biomass fuel

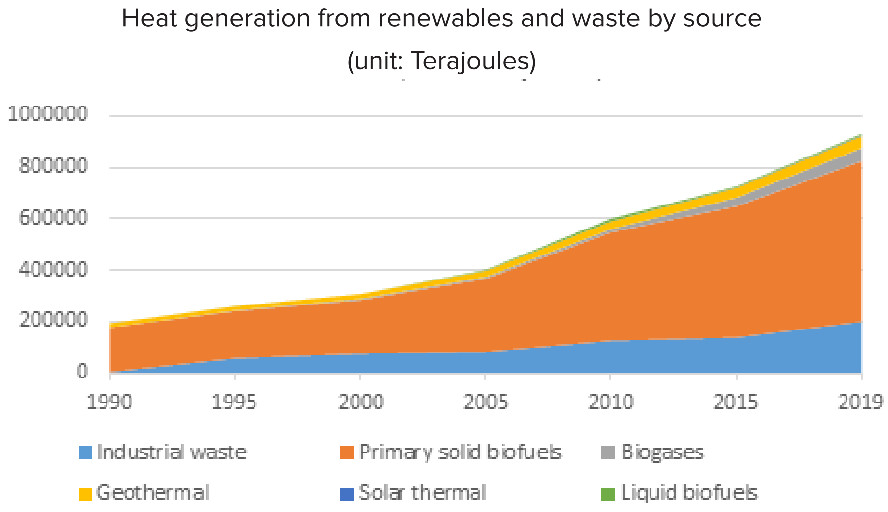
Biomass combustion systems are fueled by a form of energy derived from plant or animal matter such as wood, straw, grass, and manure. Wood is a common biomass fuel used in areas where there is an adequate supply of wood. However, except for those directly involved in the wood heating industry, the general public and heating professionals are often unaware of the benefits of this reliable and cost-effective energy source. Yet, the recent emphasis on renewable energy resources to replace conventional fuels has created a new demand for biomass (ref Figures 5 & 6).

Figure 5. World Total Energy Supply by Fuel. Source: United Nations Statistics Division (https://unstats.un.org/unsd/energystats/)



[3] FAO, Wood fuels handbook, 2015

Figure 6. World heat generation from renewables and waste by source. Source: International Energy Agency (https://www.iea.org/data-and-statistics)



The generation of heat with biomass has undoubted advantages for isolated dwellings, residential buildings and any type of non-residential building, both public and private. There are many reasons why modern biomass heating and domestic hot water systems should be used. These include the following:

- Installations supplied with biomass in its different forms (pellets, wood chips, crushed olive pits, etc.) are environmentally friendly as they have a reduced emission of pollutants into the atmosphere and do not contribute to the greenhouse effect by having a neutral CO_2 balance (Table 3). The latter feature helps to comply with climate change agreements.
- Lower fuel price compared to other conventional fuels and lower volatility, as it does not depend on external fluctuations. Even though the initial equipment investment cost is normally higher than that of equipment using conventional fuels.
- Simple operation and maintenance of the modern biomass heating systems. Considering that the biomass systems are automatic with electronic and even remote control such as the option for remote ignition through a cell phone message.
- Automatic cleaning of the equipment, in boilers with advanced technologies, making the removal of ashes a rare task.
- Highly resistant to wear and tear, biomass boilers, have a long service life and, most importantly, have a good energy efficiency ranging between 75 and 90%, depending on the equipment.
- Internationally standardized solid biofuels with specific treatments significantly favor the growth of the biomass installations market.

Table 3. Comparison of primary energy contents and CO_2 emission factors of several fuels (Source: IDAE, 2011)

Fuels					
Energy Source	Direct energy consumption		Primary Energy		Emission factor
	TOE*	Specific weight or volume	TOE	MWh	tCO_2 / TOE
Coal	1	2.01 t	1.14	13.21	4.23
Black lignite	1	3.14 t	1.14	13.21	4.16
Coking coal	1	1.45 t	1.14	13.26	4.40
Agricultural biomass	1	3.34 t	1.25	14.53	Neutral
Forestry biomass	1	2.87 t	1.25	14.53	Neutral
Petroleum coke	1	1.29 t	1.42	16.49	4.12
Coke oven gas	1	1.08 t	1.14	13.26	1.81
Diesel oil C	1	1.092 l	1.12	13.02	3.06
Fuel oil	1	1.126 l	1.11	12.91	3.18
Natural gas	1	910 Nm3	1.07	12.44	2.34
Liquefied Petroleum Gases (LPG)	1	1.763 l	1.05	12.21	2.72
Butane	1	1.679 l	1.05	12.21	2.72
Propane	1	1.748 l	1.05	12.21	2.67
Refinery gas	1	0.85 t	1.12	13.07	2.30

1.4.1. Biofuel type and availability

The development of the biomass market has led to the existence of a wide variety of solid biofuels that can be used in building air conditioning systems. Among them, the types of commercial biomass commonly used for heating systems are identified below and their thermal characteristics provided in Table 4:

- **Briquettes** generally 50-80 mm diameter and 150 mm length sawdust cylinders compressed at a high temperature, with a moisture content ranging between 10 to 20% (Figure 7). Other shapes, rectangular or prismatic, are also frequent, depending on the manufacturer. In some cases, they have holes to improve their combustion. Briquettes may be composed of crushed and densified wood or crushed, dried and molded charcoal, under high pressure. For a rough distinction the following numbers might be adopted:

• Low pressure up to 5 MPa
• Medium pressure 5 - 100 MPa
• High pressure above 100 MPa

Figure 7. Briquettes

Usually, high-pressure processes will release sufficient lignin to agglomerate the briquette. Medium pressure machines may or may not require binders, depending upon the raw material whilst low-pressure machines invariably require binders. Such external binders can be starch, clay, molasses or wood tar. All briquettes using inherent binders (lignin) or external hydrophilic binders (starch, molasses, gum, clay) are not waterproof and will disintegrate when in contact with water or stored in humid conditions.

- **Pellets:** It is a type of elongated pelletized fuel, smaller than briquettes, which is manufactured through sawdust pressing, where lignin serves as a binding agent for granules (Figure 8). Therefore, there is no need to use any other substance than the wood itself to obtain this product. The pressing process gives the pellets a shiny appearance and higher density.

Figure 8. Pellets

Wood chips, from the first and second wood processing industries or from silvicultural and forestry treatments (pruning, thinning, woody energy crops, etc.). Chip is shredded wood without any additives (Figure 9). For the production, a machine that transforms wood splinters into chips is required. The wood that should be chipped comes from trees with poor characteristics that cannot be used by the lumber industry. Another typical source of chips comes from treated wood waste subproducts such as pallets.

[4] https://cfnielsen.com/faq/what-are-briquettes/

Figure 9. Wood Chips

- **Agro-industrial waste**, such as olive pits, nut shells, almonds, pineapple, etc. (Figure 10). These biofuels are produced as a by-product of the industrial processing of almonds, hazelnuts and pine nuts. Commonly used only after drying raw material with no/few transformations.

Figure 10. Agro industrial waste

- **Firewood,** can be produced by the user himself or obtained in the market (Figure 11).

Figure 11. Firewood

Charcoal, is a solid residue derived from wood carbonization, distillation, pyrolysis and roasting (trunks and branches of trees) and from wood by-products, resulting in a solid, fragile and porous fuel with higher calorific value when compared to wood (Figure 12). Its use by mankind goes back to ancient times and is associated with the use of fire itself.

Figure 12. Charcoal

Table 4. Calorific values of main biofuels

CALORIFIC VALUES OF THE MAIN BIOFUELS			
	(kJ/kg)	(kWh/kg)	Moisture (%)
Pellets	17.000 – 19.000	4,7 – 5,3	< 15
Wood Chips	10.000 – 16.000	2,8 – 4,4	< 40
Olive pits	18.000 – 19.000	5,0 – 5,3	7 - 12
Nut shells	16.000 – 19.000	4,4 – 5,3	8 - 15
Firewood	14.400 – 16.200	4,0 – 4,5	< 20

It is important to specify which fuels are available locally (i.e., the availability of a supplier or distributor nearby), as this will be the deciding factor in determining the final choice.

An appropriate biofuel may come from the local agroforestry industry, which produces waste biomass, municipal forest residues, agricultural crop residues and wood processing.

It is therefore important to check at the outset whether suitable residues from agroforestry industries, locally produced wood chips or pellets and briquettes from supplying companies are available.

The availability of biomass and its type is essential for boilers installation. When several types of biofuels are available, it is recommended to compare the advantages and disadvantages of each type. A brief analysis of some of the biomass fuels is provided in Table 5.

Table 5. Pros and cons of different type of biomass

Type	Pros	Cons	Consideration
Wood Pellets	- High calorific value. - Very low ash content, reducing operation and maintenance needs - Pellet boilers are very efficient. There are even pellet condensing boilers - Traded internationally, with a constant composition - Utilized with standard wood type compositions in Europe	- High price compared to other biomasses. (i.e. double than firewood or wood chips)	- Storage in an isolated and dry place - No need for drying or treatment once produced - Standardized production leading to high operation reliability and less boiler operation and maintenance effort - Costly due to the preparation treatment

Wood Chips (Class 1 & 2)[5]	- Production cost is lower than that of pellets due to the lesser processing required - Clean bark and dry chips (class 1) are normally of high quality - Medium degree of standardization at the European level	- Larger storage space due to the lesser density compared to the pellets and olive pits - The lesser density justifies the transportation cost for up to 50 km as a replacement for a bigger wood volume of the same calorific generation	- Variable composition given the source of raw material. Less control in raw material when sourced directly from forests. More control when trunks are the raw material, for pellets - Requirement for natural or artificial drying of the raw material to meet the humidity of less than 45%, or even less than 30% in the case of the best class 1 chips - Ash content of less than 1% (class 1) or 5% (class 2)
Agro – Industrial Waste	- Availability and types (abundance of products and quantities) - Large productions in agricultural countries - Lower production cost as they are by-products of a process - High calorific value, but caution must be taken with the quality of the biomass to be acquired, avoiding biomass with unwanted residues such as Plastics, bags, strips… not organic materials.	- Higher ash content, although acceptable, requires greater maintenance work	- Seasonal biomasses, requiring a prior direct, agreement with the supplier early in the season - Variable composition
Firewood and briquettes	- Higher calorific value of briquettes compared to firewood or chips. - Less ash production, facilitating the cleaning and maintenance of the boiler	Higher production cost (approximately double) than that of firewood	Infrequent and practically exclusive use in small boilers (<25 kW) with a medium degree of automation, since it is necessary to introduce firewood or briquettes several times a day (cold days)

1.4.2. Biofuel sourcing

Biofuel could be acquired from a handful of sources as listed hereafter:

Forests - Forest management and harvesting, both for protection and timber commercialization purposes, are the primary sources of solid biomass fuels, typically from cleaning, pruning and tree felling operations.

[5] Class A is virgin wood (not chemically treated). A1 Moisture <= 25%, Ash <=1% / A2 Moisture <= 35%, Ash <=1,5%.

The drawbacks and/or concerns associated with professional forest exploitation are dispersion, difficult accessibility, variety of tree sizes and composition, competition in terms of using these sources for other purposes (wood-based panels, industry or paper mills), the presence of impurities (stones, sand, metals) and high moisture content. These factors have slowed down the widespread use of these products as solid biofuels.

Agriculture - Pruning olive trees, vineyards and fruit trees are the main sources of solid biomass from agriculture. The main drawbacks to their use, in addition to their seasonality, are collection optimization and their transportation. Herbaceous agricultural residues are obtained from the harvest of some crops, such as cereals (straw) or corn (stover). Again, source availability depends on the seasonality and variation of agricultural production.

Forest and agricultural industries' residues - Chips, bark or sawdust from primary and secondary industries processing wood, fruit stones, shells and other food industry residues (olive oil, pomace, canning, nuts...) form a significant share of many industrial solid biofuels. In these cases, their seasonality is due to variations in industrial activity.

It must be noted that certain residues or by-products should be treated carefully because they may contain other undesirable materials or substances, such as paint, adhesives, inorganic materials (nails, screws, etc.) which affect the quality and safety of the product obtained and the integrity of the process.

Energy crops. Crops specifically grown for energy use (typically, fast-growing species). There are many demonstration projects which are under assessment. Among the various agricultural herbaceous species likely to become energy crops are thistle, sorghum Ethiopian canola, and among tree species, poplars, eucalyptus and paulownia, the latter two species having lower water demands than poplars.

1.4.3. Biofuel storage and operation

STORAGE

Particulate biofuels can be stored outdoors or indoors.

Indoor storage protects the fuel from precipitation (and often from freezing) and can eliminate the need for an intermediate storage bin (Figure 13). But indoor storage has a high capital cost and can present other problems, such as difficulty in achieving full bin capacity, oxygen depletion from biological activities if ventilation is insufficient and physical damage from pile pressure on bin walls. Indoor storage of particulate fuel can be either above ground (buildings or bins/silos) or below ground (concrete bins). Bins come in a wide variety of shapes such as rectangular or A-frame.

Figure 13. Indoor intermediate bin feeding boiler by pneumatic system

The small, automated-staged systems fuelled by particulate biomass often use a simple storage shed. Received fuel is dumped on a paved area, then moved into the storage area by a front-end loader. Moderate-sized systems use a dedicated bin or silo with direct fuel unloading into below-ground area or a conveyor from a receiving pit to the top of above-ground storage facility (Figure 14).

Figure 14. Below ground silo with screw conveyor

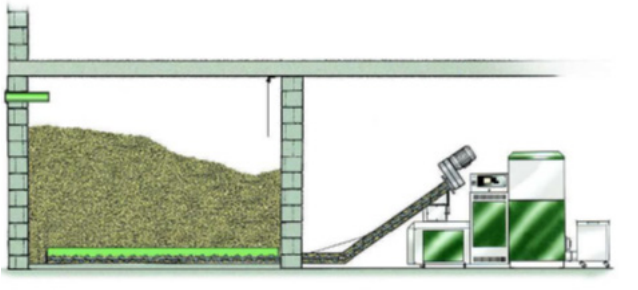


Figure 15. On the top, an adjoining 130 kg tank (Source: Arc Habitat). On the bottom, an additional 300 kg silo with worm auger feeding (+ 2000€ HT).

Silo: An additional steel mini-silo can be added next to the boiler to maintain a compact installation. Another solution is to install a larger textile silo (retention capacity between 450 kg and 8 tonnes). Table 6 shows some examples of occupied volumes:

Table 6. Storage and operation recommended

Capacity	180 kg	450 kg	2T	3T	4T	8T
Dimensions cm	L = 55 P = 41 H = 142	L = 110 P = 110 H = 135	L = 170 P = 170 H = 215	L = 230 P = 204 H = 215	L = 258 P = 258 H = 215	L = 258 P = 258 H = 240
Recharged	Manual		Blower truck			

Outdoor storage is low-cost and is easy to mix a variety of different fuels (issued from different wood species depending on availability) to create a uniform blend for better combustor operation (Figure 16). Often used in very large utility systems, outdoor storage of particulate fuel is rare in smaller installations such as those considered in this Guideline. Below are the disadvantages:

- increase in moisture content from precipitation,
-increased potential for decay in wet areas,
- greater fuel contamination from dirt pickup,
- creation of large chunks from precipitation and freezing,
- environmental problems associated with leachate runoff and wind-blown particles.

Outdoor storage also requires a second handling operation for fuel reclaim and transfer to intermediate storage.

Chunk wood for manual feed systems should be in a protected storage area preferably close to the location of the outdoor furnace. If it is obtained green and wet, the fuel should be allowed to air-dry for at least a full season before use.

The need for space for a pellet storage silo depends on the need for autonomy. Some space is also required for the pellet transfer system, which is recommended to be pneumatic by suction, this is equivalent to the volume of an industrial type vacuum cleaner.

Figure 16. Outdoor storage with intermediate silo

OPERATION (Fuel transfer)

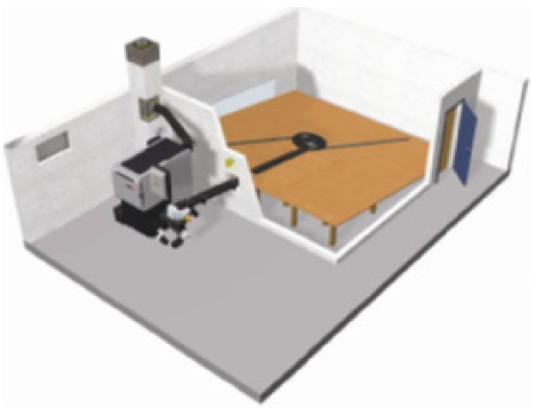
From the fuel storage (or day bin) exit, particulate fuel must be moved by mechanical conveyors to the fuel injection system of the combustor.

The movement of particulate biofuels from storage to the combustor is an important design consideration. This is called fuel reclaim. And mobile loaders normally achieve this in above-ground storage buildings (Figure 17) or live-bottom unloaders and augers in bins/silos (one such example in Figure 18).

Interruptions or delays in reclaiming fuel are directly related to fuel properties, i.e. poor flow, compaction, frozen chunks, oversize material and contaminants. Uneven filling of a bin can cause erratic operation of hydraulic scrapers and bridging over unloaders. Sticks, wire and gloves, for example, can jam augers. Manual fuel reclaim for outdoor furnaces is straightforward but labour intensive.

Figure 17. Above ground storage silo

Figure 18. Silo with crossbow system to allow good feeding of boiler



The most common conveyor for small automatic feed systems is the screw auger (Figure 17, 18, 19) either in an open or closed trough. A bridge breaker in the metering bin usually assists screw feed. Augers are relatively compact, simple and rugged but must be straight and are limited to moderate inclines. The main problem is the jamming of the auger from irregularities (sticks, frozen lumps, or stringy material) in the fuel. The overload protection (electrical or shear pin) must be carefully selected to prevent damage to the screw flights and trough covers from fuel blockages. Easy access should be provided for manual clearing.

There are many technical solutions to meet its different needs. Self-constructed and tailor-made silo. In all cases, the suction system transmits the granules to the boiler.

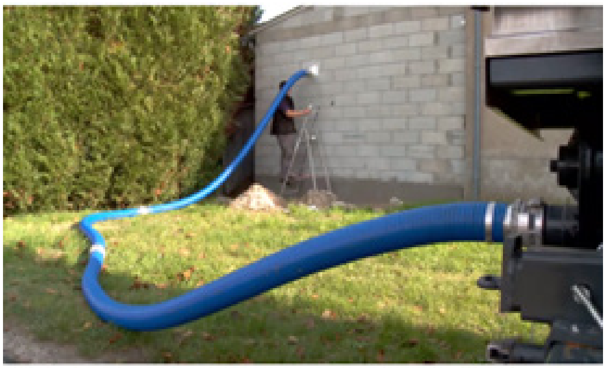
Figure 19. Pellet boiler fed by a 9-ton reserve. We can see the suction motor at the base of the silo. This model is also equipped with a worm screw

Ancillary room: Another solution is to transform an auxiliary room into a storage area with a double slope system to concentrate the granules in the middle. They are then conveyed by a worm screw and sent to the boiler.

Figure 20. Installation of an adjoining room with a funnel and screw system

Customized solutions: Given that the suction could go up to 20 meters (Figure 20), and the reserve is not necessarily attached to the boiler, any installation that meets the general requirements is possible. It can even be placed outdoors under a shelter or even buried underground (Figure 16). Automation of loading remains possible at a later stage to phase or reduce the cost of the installation

Figure 21. Blower truck (Source: Hargassner)



Reloading is usually carried out with a blower truck (Figure 21) that connects directly to the silo or auxiliary part. This is therefore effortless and does not necessarily require the presence of users.

The final step (prior to the combustor fuel injector) is often a small metering bin (Figure 23). Fuel is dumped in loads in the storage bin, so the metering bin acts as a regulator to carefully control the fuel injection rate into the combustion chamber.

The metering bin should be fully live-bottom (preferable with negatively sloped sides) to prevent bridging and has high- and low-level indicators which control fuel transfer from storage. Level indicators can be mechanical (fixed or rotating) or electrical (photoelectric or proximity).

The final transfer of fuel from the metering bin into the combustion chamber (Figure 23) can be done in several ways: a stoker auger (under, over or side-feed), a mechanical ram, a gravity drop chute or a pneumatic (often cyclonic) injector. The back flow of combustion gases through the fuel entry is controlled by lock hoppers, rotary valves or merely the flow resistance from the fuel in a screw auger. Fuel transfer is controlled separately by signals from the metering bin indicators.

Table 7 presents the pellet system part of the SE4S demonstration project case study.

Table 7. Case study of pellet system

In the Sustainable Energy for Security – SE4S project in the outskirts of Ras Baalback, due to space constraints, the option retained was to feed the hopper tank manually with classic 15 kg pellets bags, while the autonomy was ensured through the prior procurement of the season's biomass pellet demand. The boilers installed, like many others, have a version with an attached hopper tank which, when filled, gives a certain autonomy (see Figure 22 and Figure 23). In this SE4S project, the hopper capacity is 400 kg; Daily use on cold days is 10 kg of pellets (at the moment) or from before 15 L of diesel a day.

Figure 22. Boiler 31 kw with attached pellet hopper tank of 350 kg

Figure 23. Screw system conveying pellets to the burner

1.5. Sizing procedure

The biomass combustion system capacity and the size of the supplemental or backup system are crucial considerations that depend on the plant operation objective. Experienced professionals should be consulted to determine system sizing. The general objective is to achieve the lowest cost energy supply through optimal performance at high overall efficiency and the lowest operating costs. Suppliers or designers can assist in accurately sizing a system. Generally, however, there are two approaches to system sizing: Peak Load design and Base Load design. The design approach directly affects the capacity and the capital cost of your system.

A pellet boiler installation takes up space and several elements must be considered (Figure 24). Pellet boilers are not small, especially the commercialized models where safety distances are important. For example, a minimum distance of 50 to 60 cm should be kept at the back and sides (product-specific data).

Figure 24. On the top, standard boiler. On the bottom, boiler glued to the wall with upper connections (Source: Enemcon)

On the other hand, optimized models are more compact and can be placed in a corner or between two elements of a laundry room. The connections of these boilers are located on the top (smoke, hydraulics, granulate suction) (ref. Figure 25). Some devices can be integrated to a depth of 60 cm.

The buffer tank role is to keep a minimum volume of water 'in circuit' at times when the heating load is very low. This prevents the heat pump from short cycling and provides a bypass route to maintain the minimum flow rate through the heat pump if most of the heating zones have shut down. For a 10 cm insulated buffer tank, the diameter is approximately 85 cm (500L) or 99 cm (1,000L). It should be noted that the storage tank is sometimes directly integrated into the boiler.

Figure 25. ÖkoFEN Smart XS pellet boiler with integrated 335L storage tank

A description of the possible equipment to be installed is included, considering the needs for the installation of a boiler with a maximum power of 40 kW per unit. For higher power requirements, this type of model can be installed in cascade or parallel, or a single unit of higher power can be chosen depending on the needs.

It is important to choose a pellet boiler equipped with self-cleaning to avoid excessive maintenance.

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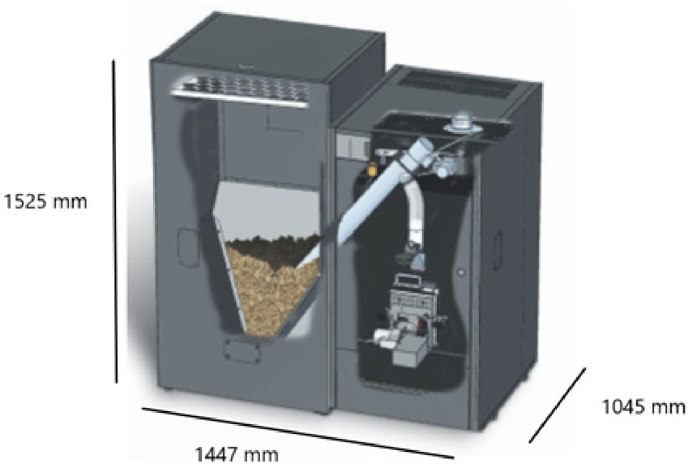
Depending on the amount of ash produced, it will be necessary to incorporate an element to compress the ash and reduce the frequency of ash pan emptying (Figure 26).

Figure 26. Compressor Ashtray

Space requirements: A boiler with these characteristics needs for assembly and maintenance the space shown in Figure 27, adding 30 cm minimum per dimension for clearance.

Figure 27. Dimension of a standard pellet boiler with hopper tank



Storage of pellets bags must be in a place protected from humidity. Boilers rooms, if space allows, is a valid option. Another option could be an adjacent / different room roofed and protected from direct rain (Figure 28).

Figure 28. Pellets bags storage

1.5.1. Peak vs. Base load design

Two methods are commonly used in the design and sizing of the heating systems:
- Peak Load Design
- Base Load Design

Table 8 below compares both methods.

Table 8. Comparison between peak load design and base load design for sizing heating systems

Method	Description	Pros	Cons
Peak Load Design	Determine the peak (or maximum) load Oversize the system by a contingency factor to meet unexpected overloads	• Minimal use of fossil fuel (backup); • Maximum use of biomass; • Increased energy use at marginal cost (if biofuel cost is low); and • Built-in capacity surplus for future load expansion	• More significant capital cost due to oversizing (larger systems) and operating costs; • Operated at partial load for an extended period of time (typical in heating applications). • Reduction of operating efficiency causing an increase in biofuel consumption; and • Increase emissions (smoke) and unstable combustion due to the boiler's high turn-down ratios

Base Load Design	Maximize cost-effectiveness by “under sizing” the system to handle only the major (or base) portion of the load. Allow a lower capital cost, smaller fossil fuel system to handle peaks.	•Higher seasonal efficiency from operating the boiler at maximum capacity for an extended time period • Significantly reduced capital costs; and • Better system control for efficient performance and lower emissions.	• the need for a conventional system to meet peak loads; and • Higher fossil fuel use.

In general, peak load sizing is more common in large installations with high continuous energy demands. Using the boilers for a base load with fossil fuel handling peaks is more often the situation in smaller installations serving exclusively space heating or variable loads.

1.5.2. Standards and certifications

European standard for wood pellets

In 2010 a European standard for wood pellets, defining the rules for the quality of pellets for the entire European territory, was firstly developed and introduced. This standard is called EU Norm EN 14961-2. It distinguishes two different quality levels: class A1 and A2, which define the best quality of pellets - from their original state (the tree) to the ash in the boiler. Class A1 is the premium quality used in private household boilers or stoves. A1 pellets produce the least amount of ash and fulfil the highest requirements. Class A2 is used in larger installations and produces more ash.

Manufacturers who produce their pellets according to this standard could be regularly controlled by private or state institutes. These “inspectors” are authorized to issue quality certificates. The only certificates, which correspond to the quality of this new European standard EN 14961-2, are called DIN plus Wood pellets for central heating boilers (an old German designation, but still valid) and ENplus Certification for wood pellet quality. All other designations are no longer valid, because they do not meet the manufacturing requirements of the EU standard.

DINplus and ENplus certificates differ in the scope of the guarantee. The DINplus guarantee ends at the factory, the ENplus guarantee ends at the boiler, i.e. until the pellets have been burned properly. If, for example, the pellets break too easily during the blowing into the silo, their quality does not correspond to the ENplus standard - but they may well correspond to the DINplus standard.

This new standard and the certification were created by the European Pellet Council (EPC) to guarantee the European consumers a high quality of wood pellets, which is essential for the boilers and the various interim storage and transport of pellets between the place of storage and the boiler to ensure its optimal performance.

Essential pellet standards

The development of the production and consumption of wood pellets for heating purposes naturally leads to the introduction of products on the market that differ in quality. Users (private and public) must therefore understand, recognize and be able to verify the essential properties that define the quality of a biofuel pellet. It is important to know their influence on the quality of combustion. Hereafter we present the essential properties identifiable by consumers for optimum use. Several characteristics define the different qualities of pellets used for heating:

- The raw material (biomass: sawdust and wood chips of leafy or coniferous wood, agricultural by-products,...) is characterized by the diversity of its physical and chemical characteristics which will naturally have an influence on the finished product (pellet).

- Types of production equipment
During the production of pellets, the raw materials can be dried by gas or wood dryers in general, belt (Figure 29) or drum dryers (Figure 30), which affect the quality of the pellet produced. The type of press used also affects certain parameters that will be discussed later.

Figure 29. Belt dryer (source https://www.perryofoakley.co.uk/)

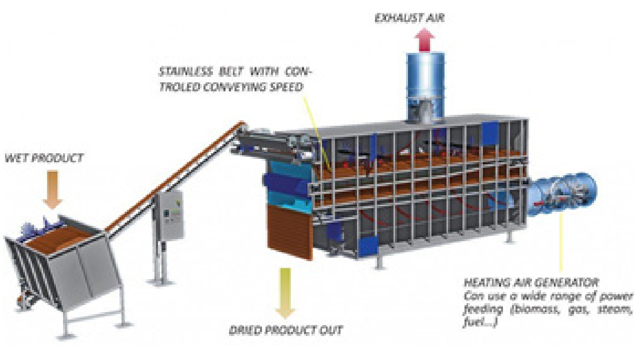
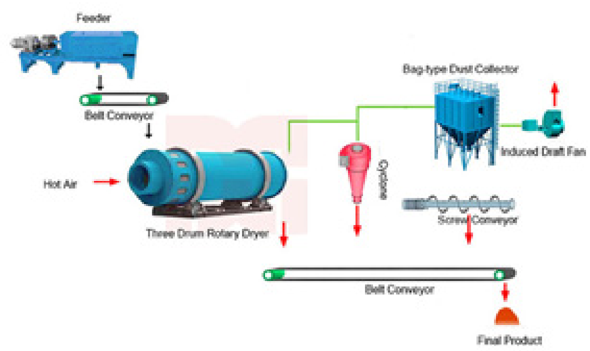


Figure 30. Rotary dryer



- The operations of conditioning and delivery
Which encompasses handling, storage (silo for bulk or bag and big bags) and delivery (blower truck, pallets,...). This last link in the chain is very important to preserve the quality of the pellet out of the factory.

- Packaging
Whatever the choices on raw materials, production materials, packaging and delivery, producers and suppliers of pellets must ensure a delivery of quality wood pellets to the end user.

Some of the characteristics that can be verified by the user are:

- The dimensions of the pellet
Most wood pellets have a diameter of about 6 to 8 mm or even 9 mm and a length of 2 to 3 cm for the pellet stove and boiler market. In some cases, they can have larger dimensions for use in industrial and collective heating. The smaller, more uniform, regular and well-densified the pellets are, the better they will flow between the silo and the boiler. Compliance with these characteristics makes it possible to avoid screw locking, which becomes very rare, if not non-existent. These properties also allow for easy delivery (by blower truck system) because the small size of these pellets allows for easy flow in the pipes.

Finally, these dimensions allow optimized storage and thus a gain of space.

- The moisture contents
Good quality pellets will have a moisture content between 8 to 10% for domestic applications and can go up to a maximum of 12 to 13% for higher power applications of industrial and collective type.

It should be remembered that the drier the wood pellet will be, the better its combustion will be and by the same token the better the performance of the heating device.

- The mechanical durability
This property represents the resilience of the pellets against breaking under the effect of shocks or friction. In other words, it can withstand the operations of loading, storage,

transport and delivery, transfer from the silo of the boiler room to the boiler, during which the pellets are subjected to shocks. The less the pellets withstand these operations, the higher the dust content of the fines, which is the percentage by mass of the products below 3.15 mm. The different size of the particles makes the pellet less resistant. An average value of durability of wood pellets is around 95%, corresponding to the percentage of pellets that do not break after the operations mentioned above.

- The rate of fines

The number of fines is an important characteristic of pellets, it can have a negative impact on the operation of a stove or boiler, especially in the transfer of pellets from the silo to the combustion chamber. The greater the number of fines in the pellets, the greater the likelihood of blockages in the feed systems. On the other hand, small fines will burn faster than wood pellets. Thus, if the pellets have many fine particles, there will be a high probability that during combustion we get an intense useless flame (which does not release part of the heat). Currently, most pellet manufacturers and suppliers ensure that the number of fines should not exceed 1%.

- Presence of additives

Additives can be inorganic or organic and cause an increase in the ash content. When their application is not controlled (e.g. formulation for agrofuels), chemicals or additional substances can have a significant influence on the particulate emissions during combustion. Pellets from agricultural products (related products, not competing with food and feed) are available on the market with controlled characteristics to ensure good combustion in dedicated heating equipment.

- The density of the pellets

Wood pellets must be sufficiently densified. The degree of densification has a strong influence on the rate of fines that can be found in the pellet. It is preferable to have a very low percentage of fines. The denser the pellet, the lower the percentage of fines. The higher the density, the higher the energy density of the pellets. This means that in the same volume (your pellet silo) you will store more energy, hence increasing the system's / installation's autonomy and reducing the delivery frequency.

ENplus certification

In October 2009 at the Inter pellets meeting in Stuttgart, Germany, and in 2010 at the European Pellet Conference in Wels, professionals in the pellet industry were able to participate in the presentation of "ENplus", a new certification developed by the Germans but with a European vocation for pellets.

"ENplus" is a voluntary certification system, which is essentially based on the draft European standard prEN 14961 (Part 2).

This certification competes with other national certifications such as "DINplus" (Germany) and "NF Biocombustibles" (France), whose standards are also in line with the European standard. These two certifications, historically national, have their advantages. The "NF Biocombustibles" certification reassures French consumers of the credibility of the AFNOR NF mark. The German certification, "DINplus", is older, better known and recognized in many countries.

The main innovation associated with the "ENplus" certification is its implementation by the industry itself throughout the production and distribution chain. It has a European vocation from the outset and is intended to be applicable in all EU countries.

It is also presented as more demanding regarding the raw material, the manufacture of pellets, logistics, storage at the retailer and delivery to the consumer. It would therefore offer customers additional security. Only the part about the ash fusibility seems to be undemanding and remains unclear.

Difference between European standard and certification

“ENplus”, like “NF Biocombustible” or “DINplus”, is a registered trademark. It is therefore associated with a certification system but should not be confused with the European standard EN, whose initials it has cleverly retained. NF, DINplus and ENplus are three quality standards that are all already based on the EN standard.

It is necessary to differentiate between the different brands and their certification systems from the official standards.

The formal definition from the International Organization for Standardization (ISO) and its sister organization, the International Electrotechnical Commission (IEC) is: a document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context” (Source: The ISO (International Organization for Standardization) and the IEC)[6].

In other words, a standard is a reference document on a given subject that indicates the state of science, technology and know-how at the time of writing. It is a standard recognized and defined within a framework regulated by the authorities. It is used to simplify contractual relations. The standard is the result of a consensus between actors (producers, users, laboratories, ...) and developed during a process called standardization.

In the case of wood pellets, the European standard provides precise definitions and figures of the characteristics that must meet the wood pellets to be good fuel. Its texts relate to:

- the main characteristics of the standardized product (pellet),
- testing and sampling methods,
- the provisions of quality assurance.

In general, there is no legal obligation for manufacturers or service providers to comply with a standard. However, this can be imposed by a client for the execution of a contract or by customers who require quality guarantees.
To guarantee that a product complies with a standard or a reference system, a certification system managed by an independent certification body is used. The latter guarantees through a control system that the product or service in question complies with the standard or reference.

Products can be certified at different levels:
- National (NF in France, DIN in Germany, Önorm in Austria...)
- European (EN)
- International (ISO)

The “ENplus” certification is based on a standard that sets requirements at the technical, organizational and functional levels. The standard, which is based on the draft European standard prEN 14961, was developed by the German Wood Energy and Pellet Association (www.depv.de) and contracted out to the German Pellet Institute. This institute manages this certification until the creation of a European association of the pellet industry. Once this European association is established, the German institute will transfer to it the rights to grant “ENplus” permits to European pellet

[6] https://www.iso.org/sites/ConsumersStandards/1_standards.html#top

producers and distributors. Eventually, this association will transfer the rights to the national pellet associations of the individual countries.

Three categories of certified products

The "ENplus" certification provides, in accordance with the standard, three categories of certified products:

- The ENplus-A1 category,
- The ENplus-A2 category and
- The EN-B category.

These different categories vary on several fundamental criteria for the quality of a good biofuel pellet (Table 9):

- the type of raw materials that can be used,
- the authorized limit value for the ash content
- the calorific value,
- the nitrogen content
- chlorine content
- ash fusibility

Table 9. Quality criteria for ENplus categories

Property	Unit	ENplus-A1	ENplus-A1	EN-B	Testing Standard
Diameter	mm	6 or 8			EN 16127
Length	mm	3.15 ≤ L ≤ 40 3)			EN 16127
Moisture Content	w-% 1)	≤ 10			EN 14774-1
Ash Content	w-% 2)	≤ 0.7	≤ 1.5	≤ 3.0	EN 14775 (550°C)
Mechanical Durability	w-% 1)	≥ 97.5 4)		≥ 96.5 5)	EN 15210-1
Fines (<3.15 mm)	w-% 1)	<1			EN 15210-1
Net Calorific Value	MJ/kg 1)	16.5 ≤ Q ≤ 19	16.3 ≤ Q ≤ 19	16.0 ≤ Q ≤ 19	EN 14918
Bulk Density	kg/m³	≥ 600			EN 15103
Nitrogen Content	w-% 2)	≤ 0.3	≤ 0.5	≤ 1.0	EN 15104
Sulfur Content	w-% 2)	≤ 0.03		≤ 0.04	EN 15289
Chlorine Content	w-% 2)	≤ 0.02		≤ 0.03	EN 15289
Ash Melting Mehaviour	°C	≥ 1200	≥ 1100		EN 15370

1) As received 2) Dry basis 3) A maximum of w-% of the pellets may be longer than 40 mm, no pellets > 45 mm allowed 4) Deformation temperature, sample preparation at 815°C.

In comparison to the current market situation, the quality category EN-plus-A1 would correspond to DINplus. The EN-plus-A2 category allows a slightly higher ash content and finally the EN-B category defines a quality that has been called industrial quality pellets until now. In the future, EN-B grade pellets will be used in large installations and power plants. Regardless of which of these categories is used, chemically treated wood cannot be used as raw material for this new certification.

One of the highlights of the new certification is the introduction of traceability: the entire delivery chain is integrated into the certification process, as the quality of the pellets will depend heavily on their route from the time they leave the manufacturing plant (or their buffer storage location) to the place where they are used by customers. Customer satisfaction is highly dependent on this delivery phase.

In practical terms, this new certification will define traceability as follows:

- Delivery notes and bags of pellets will have to indicate by attributable numbers who produced and sold them.
- To guarantee a consistently high quality of the delivered pellets, the pellet producers and traders will be certified under this system.

An accredited testing institute will carry out the certifications, which must be renewed every three years.

In practice, the two national certification systems, as well as the “ENplus” standard converge in their technical outlines because they are all intended to be an implementation of the forthcoming European standard. In the absence of standards, certification creates its own reference system and provides its own guarantee of quality. When the standard is in place, the competition becomes a competition of brand and image. Additional requirements to the standard can be added, which must be followed in detail for both “ENplus” and “NF Dual Fuel Pellets” and “DINplus”. The costs associated with the certification, paid by the producer but inevitably passed on to the consumer, must also be taken into account and certification competition must be considered.

02 OPERATIONS AND MAINTENANCE

2.1. Scope

The system manufacturer (or supplier) will provide detailed instructions for routine operation and maintenance; however, these procedures may require alteration to fit the specific requirements of the facility staff. Changes should be discussed with the manufacturer to ensure the system performance will not be adversely affected or any component warranties voided.

Biofuel systems generally require regular attention. Tasks such as ash removal and/or ash disposal, general clean-up (usually in the fuel storage and handling area), checking boiler water levels, checking the fuel delivery system for oversize material build-up, in addition to checking stack temperature and possibly flue gas composition to adjust fuel/air delivery rates are performed daily. Computerized systems can signal the operator in upset conditions or for out-of-range readings. Systems in the size range covered in this Guide (10-60 KW) usually do not have full-time operators.

In addition, there are regular maintenance tasks that are performed on a periodic basis that may vary from weekly to monthly to even yearly. These can include:

- cleaning of boiler tube;
- lubrication of mechanical component;
- inspection and adjustment of chains, gearboxes, blowers, etc.;
- refractory materials inspection and repair;
- testing of safety devices;
- checking for leaks or air infiltration; and
- inspection of insulation and cladding.

The operating characteristics of the specific system will define the frequency of the system's cleaning. Over a period, operators will become familiar with how often maintenance, such as fly ash removal, tube cleaning, stack clean-out, etc., will be required. However, until operators are familiar with this, close inspection is required.
The routine maintenance can be carried out by the system operator, by general on-site maintenance staff or by a dedicated maintenance crew or contracted to an outside maintenance and service firm.

Contracting the maintenance work is recommended when the on-site staff does not have the time or skills required for boiler system maintenance. In addition, this approach has the advantage of regular inspections by experts with specialized knowledge in the unique aspects of biofuel handling and combustion.

However, it may reduce the level of interest and dedication of the owner's staff. A maintenance contract must clearly define individual responsibilities. Generally on-site staff handle the daily tasks while the maintenance contractors address the routine preventative maintenance and repair requirements.

2.2. Recommended procedures

2.2.1. Preventive maintenance

The thermal installation shall be maintained in accordance with the operations and periodicities contained in preventive maintenance program established in the << Use and Maintenance Manual >> when it exists.

Biomass installations shall be adapted to the operations and periodicities of table 10. The maintenance operations are thosei ndicated below:

Table 10. Preventive maintenance operations

S = once every week. m = once a month, the first time at the beginning of the season. t = once per season (year). 2t = twice per season (year), once at the beginning of the season and once in the middle of the period of use, if there is a minimum difference of two months between the two times.

Action	Periodicity
Checking and cleaning, if necessary, of the boiler flue gas circuit	2t
Checking and cleaning, if necessary, of flues and chimney	2t
Cleaning of the boiler burner	m
Checking expansion vessel	m
Inspection of water treatment systems	m
Checking of refractory material	2t
Checking of sealing tightness between burner and boiler	m
Checking of water levels in circuits	m
Checking tightness of piping circuits	t
Checking tightness of interception valves	2t
Checking and cleaning, if necessary, of the boiler flue gas circuit	2t
Checking and cleaning, if necessary, of flues and chimney	2t
Cleaning of the boiler burner	m
Checking expansion vessel	m
Inspection of water treatment systems	m

Checking of refractory material	2t
Checking of sealing tightness between burner and boiler	m
Checking of water levels in circuits	m
Checking tightness of piping circuits	t
Checking tightness of interception valves	2t
Checking the setting of safety elements	m
Inspection and cleaning of water filters	2t
Inspection and cleaning of air filters	m
Inspection of heat exchanger coils	t
Inspection of pumps and fans	m
Checking condition of thermal insulation	t
Checking of automatic control system	2t
Checking of solid biofuel storage condition	m
Opening and closing of the collapsible container in solid biofuel Installations	2t
Cleaning and removal of ashes in solid biofuel installations	m
Visual inspection of the biomass boiler	S
Checking and cleaning, if necessary, of boiler flue gas circuit and flue and chimney ducts flue pipes and chimneys in biomass boilers	m
Review of safety elements in biomass installations	m
Review of environmental quality according to UNE 171330 standard criteria	t

2.3. Life expectancy

In theory, a BCS (Biomass Combustion System) can last indefinitely, since the components can be replaced as they wear out or deteriorate. In the forest industry, wood combustion systems have been in operation for over 50 years. A system may be replaced if a newer technical design provides better efficiency, lower emissions or greater flexibility or when operating costs showing the annual repair/replacement expenditures exceed the projected capital recovery costs of a new system. In practice, 15 to 20 years is used as a reasonable BCS life expectancy for the purpose of life cycle costing for systems in this Guideline.

03 FINANCIAL APPRAISAL

31. Economic analysis of the options

Economic analysis helps determine the subsidy and/or incentive required. Economic indicators of Net Present Value (NPV), Internal Rate of Return (IRR) and/or Pay Back (PB) periods are typically employed to analyze the economic performance of different scenarios and determine the use of biomass. The use of biomass from local sources decreases the reliance of the country on fuel imports, the price of which can be volatile [7].

In order to analyze the different alternatives when choosing the preferred heating system (Table 11 and 12), different type of costs shall be taken into consideration [8]:

1) Capital bound costs: annual capital costs under consideration of the investment costs (site purchase, machinery purchase, project development costs...), interest rate, inflation and the lifetime;

2) Maintenance costs: related to the maintenance of process equipment, such as fuel handling, boiler, buildings and roads; 3) Operation costs: include the effort of the end user (disposal of residues, fuel storage, salaries), insurance costs;

4) Consumption costs: include all costs related to the operation of the heating system, e.g. fuel costs, electricity consumption for lighting, ventilation, etc.

Table 11. Example of economic evaluation of boilers in Greece: specification of the boilers investigated[8]

Application		Boiler II		Stove II		Boiler III		Gas Condensing Boiler	
Fuel type		Olive stones	Wood pellets	Olive stones	Wood pellets	Olive stones	Wood pellets	Natural gas	Liquid gas
Nominal load									
Heating capacity	[kW]	28.0	28.0	21.2	21.2	40.0	40.0	30.0	30.0
Thermal efficiency	[%]	77.9	83.5	86.2	88.0	93.1	92.6	98.0	98.0
Fuel power input (related to NCV)	[kW]	35.9	33.5	24.6	24.1	43.0	43.2	30.6	30.6

[7] Sansanee Sansiribhan, Anusorn Rattanathanaophat, Sarisa Pinkham, Busarin Eamthanakul, Ammara Ittipongse, (2018)" Economic Feasibility Analysis of Wood Pellet Boiler in Thailand Industry", International Journal of Management and Applied Science (IJMAS), pp. 78-80, Volume-4,Issue-4
[8] http://biomasudplus.eu/wp-content/uploads/2018/11/BiomasudPlus-D5_4-2018-08-28.pdf

Electricity demand	[kW]	0.370	0.370	0.340	0.340	0.150	0.150	0.083	0.083
30% partial load									
Heating capacity	[kW]	8.4	8.4	6.4	6.4	12.0	12.0	9.0	9.0
Thermal efficiency	[%]	71.2	65.0	75.1	76.9	90.2	90.3	98.0	98.0
Fuel power input (related to NCV)	[kW]	11.8	12.9	8.5	8.3	13.3	13.3	9.2	9.2
Electricity demand	[kW]	0.222	0.222	0.204	0.204	0.090	0.090	0.050	0.050
Operating hours at full load	[h/a]	400							
Operating hours at 30% partial load	[h/a]	2,000							
Total operating hours	[h/a]	2,400							
Full load operating hours	[h/a]	1,000A							
Annual heat production	[MWh/a]	27.2	27.2	20.6	20.6	38.8	38.8	29.1	29.1
Annual fuel consumption	[MWh/a]	38.0	39.2	26.8	26.2	43.8	43.9	30.6	30.6
Annual electricity consumption	[kWh/a]	592	592	544	544	240	240	133	133
Annual thermal efficiency	[%]	71.5	69.2	76.8	78.5	88.6	88.5	95.1	95.1
Unit price	[€]	4,200	4,200	2,800	2,800	14,000	14,000	3,700	3,700
Additional components	[€]	500	500	-	-	7,500	7,500	-	-
Installation costs	[€]	1,000	1,000	450	450	2,500	2,500	400	400
Connection to natural gas grid	[€]	-	-	-	-	-	-	-	-
Liquid gas tank	[€]	-	-	-	-	-	-	-	9,300
Investment costs for the boiler	[€]	5,700	5,700	3,250	3,250	24,000	24,000	5,600	13,400
Maintenance costs	[€/a]	155	155	40	40	280	280	150	340
Maintenance costs	[% of invest/a]	2.7%	2.7%	0.9%	0.9%	1.2%	1.2%	1.1%	2.5%
Expenditure of time for the user	[h/a]	28	28	28	28	9	9	1	1
Labour costs	[€/h]	10	10	10	10	10	10	10	10
Labour costs	[€/a]	280	280	280	280	90	90	10	10

Table 12. Example of economic evaluation of boilers in Greece: specific heat generation cost8

Application		Boiler II		Stove II		Boiler III		Gas Condensing Boiler	
Fuel type		Olive stones	Wood pellets	Olive stones	Wood pellets	Olive stones	Wood pellets	Natural gas	Liquid gas
Nominal load									
Investment costs for the boiler	[€]	5,700	5,700	3,250	3,250	24,000	24,000	5,600	13,400
Building costs	[€]	5,000	5,100	-	-	7,200	7,100	400	400
Total investment costs	[€]	10,700	10,800	3,250	3,250	31,200	31,100	6,000	13,800
Capital bound costs	[€/a]	716	722	252	252	2,255	2,249	422	944
Maintanence costs	[€/a]	233	234	45	45	400	399	175	268
Operation based costs	[€/a]	474	475	389	389	491	490	114	202
Fuel costs	[€/a]	1,497	2,577	1,055	1,718	1,727	2,878	2,383	2,912
Electricity costs	[€/a]	101	101	101	101	45	45	25	25
Total costs per year	[€/a]	3,030	4,118	1,843	2,506	4,917	6,061	3,119	4,351
Annual heat production	[MWh/a]	27.2	27.2	20.6	20.6	38.8	38.8	29.1	29.1
Specific heat generation costs	[€/ MWh]	112	152	90	122	127	156	107	150

In general, there are two main potential scenarios to assess when comparing a biomass combustion system project and an alternative system project[9]:

1. New facilities. Under this case, there is no heating plant in place. Therefore, all costs of a new biomass boiler installation project would be compared to all the costs of installing and operating the alternative (e.g: an oil boiler).

2. Retrofit of existing facilities. In this case there is a conventional heating system (say an oil burner/boiler) in place. All costs of a new biomass boiler installation would therefore be compared only to fuel savings. The existing system investment costs have already been made and therefore are not considered. Only annual costs would then be compared to those of the biomass boiler.

The analysis can be a bit more complex if the existing oil boiler is used as backup and the existing heating distribution system is used. On the other hand, if the existing oil unit is due for replacement, then the analysis would assume heating plant costs for both the biomass boiler and the oil system.

An economic analysis presents the project's viability from a society's perspective over the project lifetime and given a series of assumptions . To evaluate a project's economic viability, the analysis presents the project's net present value based on the estimated costs and benefits to society. Furthermore, the analysis should clearly present the underlying assumptions[10] such as the national discount rate and project lifetime and report results such as the net present value, the internal rate of return, and the cost/benefit ratio.

LOCAL ECONOMIC BENEFITS AND COSTS

The use of biomass boilers has impacts on the local economy. The potential positive and negative local effects of a biomass-based project are as follows:

Benefits:

• A possible increase in income for local farmers as a result of local demand for biomass.

• The potential creation of local employment (either at the generation plant or in the agricultural/forestry sectors).

• Possible infrastructure improvements, such as grid connection or improved roads for biomass transport.

Costs:

• Negative environmental effects due to emissions from users.

• Social effects should be carefully considered. If the biomass to be used for energy production is currently used by locals, the use biomass may cause social issues.

PUBLIC ECONOMIC BENEFITS AND COSTS

Biomass projects may have an impact on the macroeconomy, and can provide several other macroeconomic benefits (Figure 31), such as:

Benefits:

• A stable energy supply.

• Decrease of subsidies for fossil fuels in public budget (if applicable).

• Improved opportunities for industrial production, and thereby job generation, due to the stable energy supply.

• National increased security of energy supply, making the country less dependent on import of foreign energy sources.

• Reduction of greenhouse-gas emissions, as energy from bio-waste implies less emissions compared to alternative fossil-based energy sources.

• Other environmental benefits from reducing alternative fossil fuel-based electricity generation.

• Reduced health costs and better overall air quality from pollution externalities.

Costs:

• No negative environmental effects, unless primary biomass is used for energy generation. This would undermine the sustainability of the project, causing an overall global increase in greenhouse-gas emissions.

• Negative economic effects: Capital expenditures and operation and maintenance costs, potential risk posed by foreign currency exposure to exchange rate volatility.

Figure 31. Approach to economic analysis

Source: COWL

3.2. Financial analysis for biomass pellet boilers for Lebanon

Based on the project Sustainable Energy for Security Project (SE4S) funded by the European Union and implemented by the UNDP, a financial analysis of the installation and operation and maintenance of a pellet boiler is provided herein, based on the actual implementation of 13 pellet boilers for the Lebanese Armed Forces. The financial analysis will provide the benefits of installing a biomass pellet boiler in comparison to a similar capacity diesel boiler.

The pellet boiler installed are of 31 kW capacity each, with a turnkey supply and installation cost of $18,000 per boiler. In the future, we expect the costs of similar pellet boilers in Lebanon to drop once and if the market for biomass boilers expands further. A similar diesel boiler in Lebanon costs $10,000. The maintenance of the pellet and diesel boilers are assumed at 2.7% and 2.5% of investment costs, respectively, as per Table 11.

The price of pellets and diesel on the other hand fluctuates, yet higher chances are, reality is that higher diesel fuel prices will always be accompanied by relatively higher biomass pellet prices.

Therefore, we will adopt the average price of diesel fuel and biomass pellets . Table 13 indicates the assumptions adopted for the financial appraisal of biomass pellet boilers in Lebanon, in comparison with a diesel boiler.

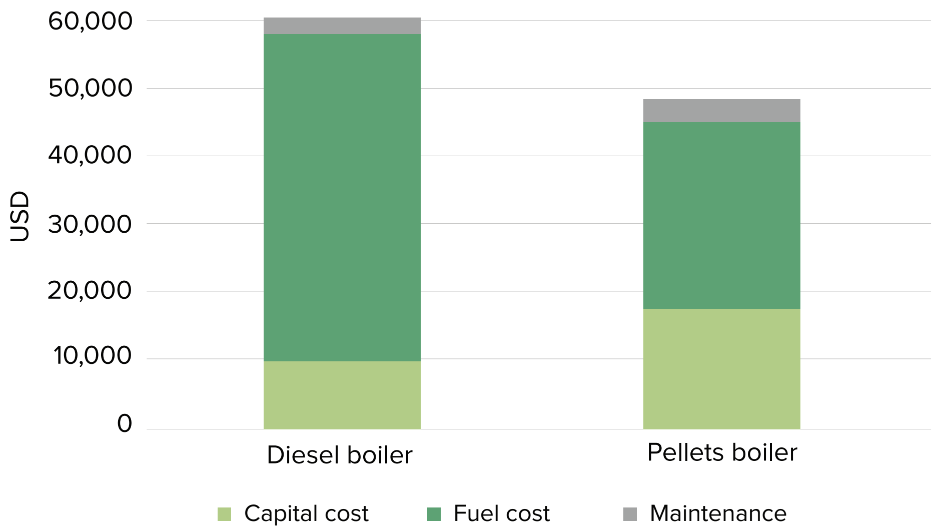
Category	Pellet boiler	Diesel boiler	Reference
Capital cost (USD)	18,000	10,000	SE4S Project
Maintenance costs	486	250	Based on Table 11
Fuel cost (diesel - $/ton)	-	1000	Based on Lebanon 2021 – 2022 average
Biomass Pellet cost ($/ton)	210	-	Based on SE4S Pellet Costs
Amount of fuel (diesel) consumed by boiler per season (tons)	-	7.2	Based on LAF needs per outpost at North-Eastern Border (6 months season)
Amount of biomass consumed by boiler per season (tons)	18	-	Based on LAF needs per outpost at North-Eastern Border (6 months season)
Life-time (Yrs)	15*		https://www.eco-home-essentials.co.uk/disadvantages-of-biomass.html & https://www.theecoexperts.co.uk/boilers/how-long-does-a-boiler-last
Discount rate	12%		UNDP, 2021. Climate-Proofing Lebanon's Development Plans. Beirut, Lebanon

* Biomass pellet boilers are referenced to last between 18 to 20 years, however we adopt a conservative estimate of 15 years.

Results indicate that the net present value of costs of supplying, installing, operating and maintaining a boiler over 15 years is $60,741 for the diesel boiler and $38,460 for a biomass pellet boiler.

The contribution of the net present value of cost categories (capital costs, maintenance costs and fuel costs) are shown in Figure 32.

Figure 32. Net Present Value of Costs per Category



As shown in Figure 32, fuel is the main contributor of costs, specifically for the diesel boiler case. Maintenance costs for both boilers are minimal, whereas capital costs are substantial for the pellet boiler case.

The Net Present Value of installing a biomass boiler instead of a diesel boiler is $22,281.

Another scenario that is more practical is one that assumes the diesel boiler is already installed (as was the case in the SE4S project), and to analyze the added value of replacing the diesel boiler with the biomass pellet one. In this case, the net benefits would mainly be the diesel fuel costs savings, whereas the costs would be the capital costs of the biomass boiler, the additional maintenance costs (0.2%), and the pellet fuel. Figure 33 shows the cumulative cash flow from such a decision, using 12% discount rate.

Figure 33. Discounted cumulative cash flow analysis (replacing diesel boiler with biomass)

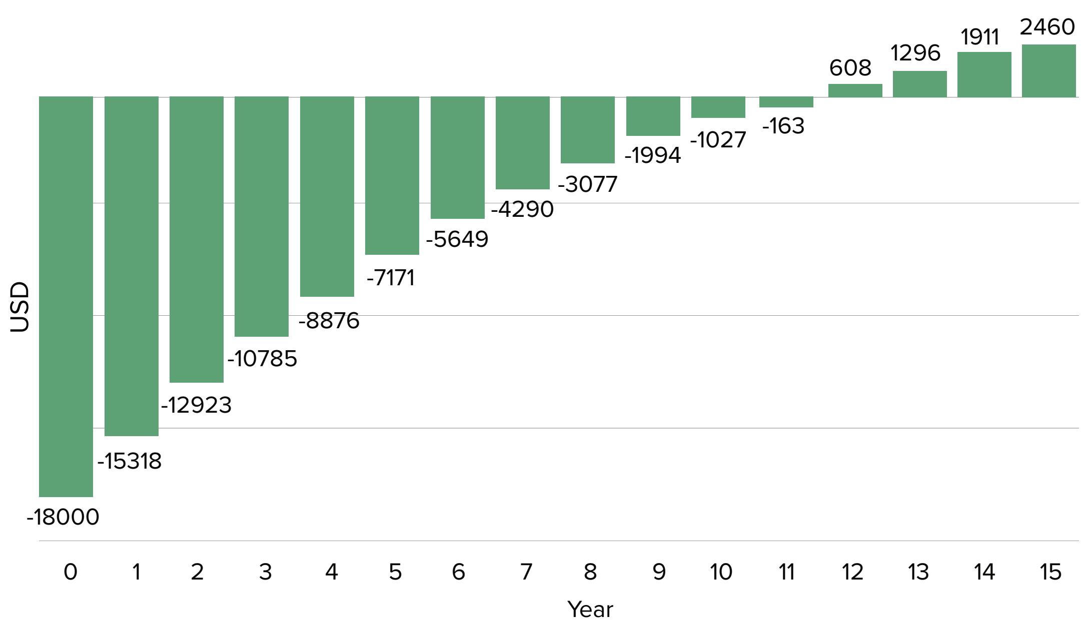


Figure 33 assumes that the capital cost is the biomass boiler investment, whereas this investment is not assumed to save on the cost of a diesel boiler as the latter is a sunk cost investment that we are displacing. The analysis shows that the payback period occurs just after year 11.

The analysis clearly shows that in both cases the biomass pellet boiler will yield better financial outcomes than a diesel boiler. This is the case when deciding between the purchase of a biomass boiler or a diesel boiler, or when and if deciding to replace an existing or already installed diesel boiler with a biomass pellet boiler.

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