MASTER THESIS

The Potential of Wood-Based Bioenergy in the Basque Country

Final Version of the Thesis
August 6, 2018

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MASTER OF ENVIRONMENTAL AND ENERGY MANAGEMENT PROGRAM

UNIVERSITY OF TWENTE.

ACADEMIC YEAR 2017/2018

ABSTRACT

The research for this thesis consists of the study of the potential that Basque forests have to be a sustainable source of bioenergy in the region. Energy is a crucial element for fighting against climate change, and as a result, the development of renewable energy sources like bioenergy are necessary. Also, renewable energies would generate local benefits and more energy independence for the region. The research aims to estimate the maximum potential that Basque forests have to be used as sustainable energy sources. The research will be analyzed using perspectives from ecology, forestry, management models, and sustainability. The primary data for this research is from different organizations of the Basque government, such as the department responsible for forestry, energy, and public management, also, scientific documents that contain information and different processes for bioenergy. The secondary data will be used to analyze what is done in other countries for comparison. It will also be used to support the primary data. The recommendation will be generated directly from the combination of ecology and sustainability for different sectors of the region and public institutions in a general way.

Table of Contents

ABSTRACT 2
CHAPTER 1 INTRODUCTION 5
1.1 Background 5
1.2 Problem Statement 6
1.3 Research Question and Goals 7
1.4 Methodology 8
1.5 Outline 8
CHAPTER 2 THEORETICAL FRAMEWORK 10
2.1 The Basque Country 10
2.2 Energy Situation of the Basque Country 11
2.3 Basque Forests 12
2.4 Biomass and Bioenergy 18
2.5 Woodchip Bioenergy 20
2.6 Wood Energy in the European Union 21
2.7 Legal Situation 22
2.8 Sustainability and sustainable management of the forests 23
CHAPTER 3 RESEARCH DESIGN 25
3.1 Research Question 25
3.2 Research Material and Accessing Method 25
3.2.1 Required Data and Information 25
3.2.2. Source and Method of Data Collection 26
3.3 Research Methodology 26
3.4 Research Strategy 37
3.4.1 Research Boundary 37
3.5 Defining Concepts 38
CHAPTER 4 CALCULATION OF THE POTENTIAL 39
4.1 Elimination of Inadequate Species (Step 1) 39
4.2 Protected Nature Areas (Step 2) 40
4.2.1 Nature Parks 41
4.2.2 Protected Biotopes 41
4.2.3 Special Trees 42
4.2.4 Natura 2000 Areas 42

4.2.5 Biosphere Reserve 42
4.2.6 Effect of Protected Nature Areas on the Forests Potential Calculation 43
4.3 Extensive and Intensive Forest Uses (Step 3) 44
4.3.3 Tree Species in Extensive and Intensive Forest Use 44
4.4 Wood Extraction of the Forests 47
4.4.1 The State of the Mass in Hardwood Forests (Step 4) 47
4.4.2 The Density of Trees in Hardwood Forests (Step 5) 49
4.4.3 State of Mass in Conifers and Eucalypts Forests (Step 4) 51
4.4.4 The Density of Trees in Intensive Forests (Step 5) 52
4.4.5 Total Wood Extraction Potential 53
4.5 The Energy Potential of Basque Forests 54
CHAPTER 5 CONCLUSION 57
CHAPTER 6 RECOMMENDATIONS 59
REFERENCES 61
APPENDIX 76

CHAPTER 1 INTRODUCTION

1.1 Background

Energy is the key element to developing societies; its development and improvement will condition our future. The current global energetic system, based on nonrenewable energy sources, has caused significant environmental damage and will generate more if we do not change the model worldwide. Countries, and especially the EU, are trying to substitute the use of nonrenewable energy sources that will disappear in a short-medium period and harm our environment for renewable energy sources like sun, wind, water or biomass energy. The global warming process that our planet is suffering will also need to be considered.

Renewable energy is the energy generated from natural processes that are continuously replenished; this includes sunlight, water, tides, wind, geothermal heat, and various forms of biomass (Ciolkosc, 2017). Renewable energies are known as clean energy or green energy because they do not affect the environment as much as fossil fuels do. The positive aspect about these renewable energies is that they do not generate any Green House Gas (GHG) emissions. Every region in the world has a type of renewable energy source available in abundance. In the Basque Country (a Spanish region), the renewable energy that is most abundant is wood (bioenergy source) due to the vast amounts of forests available. Bioenergy consists of the use of biomass, like wood, as a fuel to generate electricity or heat.

Wood is an energy source that is already being used in the region to generate electricity and heat. When added to other bioenergy sources, like biogas and municipal waste incineration, they represent around 5% of the total energy demand of the Basque Country (*Azterlanak eta Planifikazioa Atala*, 2017, p. 13). This research estimates that the potential of bioenergy, and specifically wood energy, have is high and it should be utilized more for energy production purposes. For that, this research aims to estimate the maximum potential that Basque forests have to produce wood annually, and the energy potential that this wood has while respecting native species. It is a research that has not been done in the Basque Country and could give insight to the authorities, public institutions, private companies, and individuals.

1.2 Problem Statement

Low levels of renewable energy use create two main problems for the inhabitants of the region. The percentage of the renewable energies in the energy mix of the Basque Country is 7.5%, a low percentage when compared with other European countries (average of 17%) and with Spain (17%) (Eurostat, 2018).

The combustion of gas, coal, and oil products generate pollution that worsens the quality of the environment and the health of the people; they also produce greenhouse gases that globally are affecting our atmosphere and climate, making the process of global warming stronger. The European targets for Spain, and the EU itself, in renewable energy generation are 20% for 2020; the Basque Country is far from accomplishing them although there is not any specific target for this region in particular. This region has to collaborate with the Spanish objectives to achieve the national goal (European Commission, 2010). The EU is developing new energy plans and energy targets for 2030 and 2050 that will have much higher renewable energy targets that if not respected will bring economic sanctions.

Another problem is that the region's energy self-supply rate is 7.1%, that means that more than 90% of the energy is coming from other places around the world (*Azterlanak eta Planifikazioa Atala*, 2017, p. 9). This region is more dependant on energy from other places than other regions in Spain. Because of this, the Basque Country becomes very vulnerable to external factors. A change in the geopolitical situation could make the energy security of the region disappear.

Another problem with the low self-supply rate is economic. Much money goes to other countries to buy different types of energy, and it generates a deficit of many millions in the country. Local renewable energy sources have the potential to push the economy of the region and its people, eliminating part of the deficit and creating new jobs (Redacción Interempresas, 2012). The energy market in the Basque Country moves every year around 5,603 million Euros, and it is the 10% of the Basque gross domestic product (Ormazabal, 2016). Wood-based energy generation could minimize the deficit in millions of Euros. For that, these renewable energies should be able to compete economically with other energy sources.

1.3 Research Question and Goals

The research aims to answer the question of what is the annual wood biomass potential of the Basque forests, and what is the annual energy potential of the wood biomass while respecting native species.

The main objective of the research is to calculate the potential that the Basque Country has to generate bioenergy using their forests and while respecting native species. For that, the different forests of the region will be analyzed with their main species and its biological cycles.

Another objective is to create a new method to calculate the potential that forests have to be a sustainable and renewable energy source in a specific region. This method could be used in other places with the same objectives. This method allows us to know the maximum potential that forests have and make conclusions so authorities can develop plans.

The last objective is to understand the current situation that Basque forests have and find the strengths and weaknesses.

The research will show the maximum annual wood biomass that Basque forests can produce respecting native species in tonnes, and the energy that this wood quantity could produce in TJ.

1.4 Methodology

The key information of the thesis is based on the forest inventory made by the Basque government in 2017. This forest inventory divides different forests by their tree species, their area, their density, and property.

The methodology divides forests into two groups: leafy or hardwood forests (native species) and conifers and eucalypts forests (no native species). These two forest groups will have different wood production levels. Conifers and eucalypts will have higher wood production levels per hectare because these species produce more wood and have a very low environmental value, which is why they can be used intensively. In the case of hardwood forests, they will have lower wood production levels per hectare because these species produce less wood and have high environmental value, which is why they have to be used with a lower intensity aiming the protection and sustainability of these forests and ecosystems.

After dividing the forests into two groups, each group's potential will be calculated depending on the maturity of the forests and their tree density level per hectare.

1.5 Outline

Chapter 2 explains basic concepts that are important to understand the research as what the Basque Country is and its energetic and forest situation. After, what bioenergy and wood energy are will be explained, and its situation in the European Union. To end the chapter, the legal situation of bioenergy production and the sustainability concepts the research has on forests and their management will be explained.

Chapter 3 explains the methodology of the research to calculate the potential that Basque forests have to be a bioenergy source while respecting native species.

Chapter 4 shows the different steps in the calculation of the potential, the findings, and the results of the research.

Chapter 5 is the concluding chapter in which it has summarized the content of the research and where it has answered the research question. The conclusions of the research, and after the suggestions are explained.

After the bibliography, there is an appendix that aims to explain the forest situation of the Basque forests in more detail.

CHAPTER 2 THEORETICAL FRAMEWORK

2.1 The Basque Country

The Basque Country is an autonomous community located in the north of Spain that includes the provinces of Araba, Gipuzkoa, and Bizkaia (Biscay). The capital is located in the city of Vitoria-Gasteiz (Araba), and the most populated and important economic region is Bilbao (Biscay). The autonomous community is 7,229 square kilometers (around 1.4% of Spanish territory) and has a population of 2,176,577 people (Eustat, 2017). The Basque Country borders the Bay of Biscay and France.

Figure 1. Location of the Basque Country (Eupedia.com, 2018).

Figure 2. Provinces and capitals of the provinces of the Basque Country (Redactor, 2016).

2.2 Energy Situation of the Basque Country

Knowledge of the current situation of energy generation and consumption in the Basque Country is necessary to understand the strengths and weak points of the local energy system. For that, official webpages, energy strategies, and annual reports will be used. The official site from the Basque Government, EVE, (Basque Energy Institution) will be used to take most of the information.

The total demand for primary energy or domestic consumption in the Basque Country was 260,977 TJ in 2017. The energy system of the Basque Country is based on the consumption of fossil fuels like oil and gas (78%). The production of primary energy, which corresponds to renewable energies represents 6.8% of the energy demand (*Azterlanak eta Planifikazioa Atala*, 2017, p. 13). The consumption of renewables in the total energy consumption is the 7.5%. In comparison with Spain and the EU, the share that renewable energies have in energy production is low; the share was 17%, in both the EU and Spain, in 2017 (Eurostat, 2018).

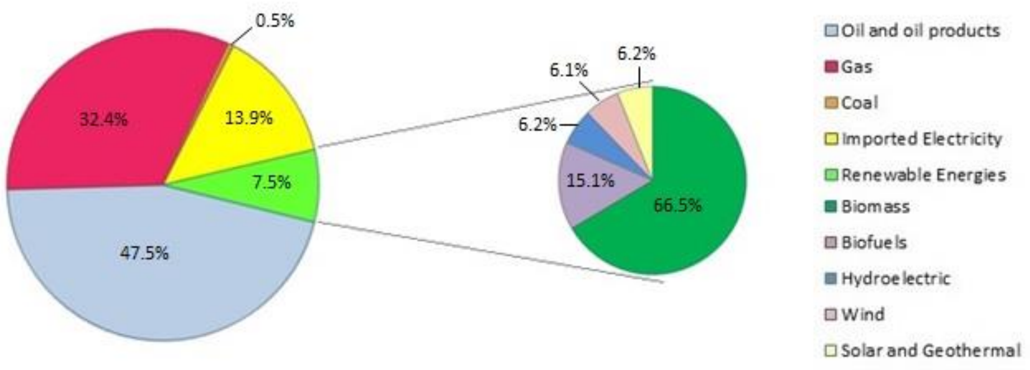


Figure 3. A circle graph of the total energy consumption in the Basque Country, 2017 (*Azterlanak eta Planifikazioa Atala*, 2017, p. 13).

Of that small renewable generation amount, biomass is responsible for 66.5%; biofuels, 15.1%; hydroelectric power stations, 6.2%; wind, 6.1%; and solar and geothermal, 6.1%. The total energy generation of renewables was of 19,596 TJ in 2017.

Compared with Spain and the EU, the percentages of biomass and biofuels are higher than average, and wind energy generation is especially low.

In figure 3, it seems like bioenergy is already a very used and developed renewable source in the Basque Country, but it is not true, the percentage of bioenergy is so large because wind and solar energy have almost not been developed (Energias Renovables, 2016). As mentioned before, the Basque external energy dependence is over 93%, a factor that is negative for the economy and other aspects. Energy plans of the Basque government and the European Union for 2020, 2030, and 2050 plan the improvement and multiplication of the use of renewable energy sources (Ente Vasco de la Energía, 2017).

2.3 Basque Forests

By usage, the forest area, including trees and forests (pasture, scrub, rocks) covers 490,027 hectares, 68% of the surface of the autonomous community (Inventario forestal CAV). The wooded forested area covers 54.9% of the total surface of the autonomous community. The surface of hardwoods (native species) exceeds that of conifers, although the extension of forest plantations continues to exceed, by a small margin, that of natural forests. Most of the information about forests is taken from the forestry inventory of 2017 from the Basque government. The public institution called Hazi conducted research on Basque forests and calculated that in 2015 there were 62,600,000 m^3 of wood in the Basque forests and it increases every year by 3,300,000 m^3 (Altuna, 2012).

Below is a table that explains different extensions in forest situations in the Basque Country and in its three provinces:

Surface in ha	Araba	Biscay	Gipuzkoa	B.C. (2016)	B.C. (2011)	B.C. (2005)
Total area	303.614	221.93	197.838	722.945	722.439	722.439
Wooded area	141.211	132.222	123.790	397.223	396.961	396.701
Leafy area	102.126	52.276	58.232	212.634	204.963	201.164
Conifers area	39.085	79.956	65.558	184.589	191.999	195.537
Forest plantations	30.559	101.707	74.865	207.131	209.027	209.508
Public mountain	148.164	45.185	35.611	228.959	226.844	224.934

Table 1. A table of the wooded area in the Basque Country (Inventario forestal CAV).

On the next page there is a table that explains the current situation of Basque forests like the different species, their forest areas, and other important factors.

Distribution of forest species(ha)									
	Estate of mass					Density			Property
	Cuts	Young	Medium	Grown	Total	Low	Medium	High	%Público
Pinus sylvestris	16	175	349	16,971	17,511	978	3,979	12,468	79.7
Pinus halepensis	1	262	211	325	798	492	200	55	44.2
Pinus nigra	129	770	2,198	10,788	13,885	1,546	5,582	6,450	62.7
Pinus pinaster	112	543	1,155	4,958	6,768	1,009	2,596	2,966	52.2
Pinus radiata	6,751	14,290	17,989	84,891	123,921	13,284	43,080	54,591	14.8
Picea abies	4	12	22	516	554	24	116	403	73.6
Pseudotsuga menziesii	49	1,371	1,287	4,653	7,360	784	1,511	4,358	31.9
Larix spp.	139	155	222	7,399	7,915	83	523	7,100	26.4
Chamaecyparis lawsoniana	82	57	109	3,049	3,297	77	500	2,621	56.5
Other conifers	8	1,230	928	415	2,581	658	849	630	47.1
Total conifers	7,289	18,865	24,471	133,965	184,590	18,935	58,935	91,642	28.6
Quercus robur	32	996	3,817	11,078	15,924	311	1,511	13,584	42.0
Quercus petraea	1	38	137	497	674	13	24	615	58.7
Quercus pyrenaica	3	320	4,047	8,740	13,110	102	549	12,433	90.8
Quercus faginea	38	1,534	20,288	4,804	26,665	3,766	7,418	15,373	72.0
Quercus ilex	13	2,164	22,110	2,077	26,364	2,282	9,671	14,192	71.8
Riverbank forests	5	81	3,138	1,322	4,547	598	2,026	1,893	15.1
Alnus glutinosa	1	12	193	606	811	12	114	677	58.2
Salix spp.	0	91	98	5	194	86	60	45	21.6
Leafy plantations	7	1,813	1,112	678	3,610	590	977	1,424	41.0
Eucalyptus globulus	639	3,004	1,468	5,783	10,894	2,613	4,144	2,154	9.9
Eucalyptus nitens	237	3,886	754	1,478	6,355	2,321	1,155	551	14.0
Other Eucalyptus	49	90	113	693	945	515	226	95	88.7
Robinia pseudacacia	12	82	357	526	977	49	81	819	16.2
Quercus rubra	15	792	1,073	2,028	3,907	116	429	2,996	51.4
Platanus spp.	7	2	59	227	294	10	86	191	5.5
Populus alba	5	58	57	277	397	109	129	131	7.9
Populus nigra	2	29	73	4	109	12	76	9	0.3
Fagus sylvatica	13	1,886	4,276	48,443	54,619	868	3,713	49,350	74.0
Castanea sativa	3	136	391	633	1,163	15	99	1,005	63.1
Betula spp.	1	174	333	139	647	56	137	382	73.0
Fraxinus spp.	0	132	221	470	824	93	121	559	70.2
Mix forest of cliff	0	23	383	17	423	1	173	249	48.4
Atlantic mixed forest	196	3,043	19,811	12,365	35,414	700	6,303	28,159	9.8
Other leafys	16	1,042	1,760	948	3,767	302	958	2,050	53.5
Total leafys	1,297	21,427	86,069	103,839	212,633	15,540	40,181	148,937	53.0
Total species	8,586	40,292	110,540	237,804	397,223	34,475	99,116	240,578	41.7

Table 2. Distribution of tree species in the Basque Country (hectares) (Inventario Forestal CAV).

The knowledge of the area that each species covers is an important factor in developing the research because each species has its own characteristics and biological cycles that affect the productivity of wood and other factors. It is also important to know the age of the forests and each species and the density of them to make conclusions. The ownership of these forests (public or private) will also be crucial for the future use of these lands. All of this information is collected in the table above.

Biodiversity is a term used to refer to the richness and variety of forms that life can adapt; from the variety of genes, animal and plant species, races that exist within the same species, landscapes, and ecosystems (Eusko Jaurlaritza, 2014). The biodiversity of the Basque forests is still quite high thanks to the different habitats and climate that can be found in this small region but has been affected this last century due to the expansion of forest plantations and non-native tree species. Biological diversity is not only valuable in itself; it is the basis of the functioning of ecosystems and, therefore, the basis of our health and prosperity (Edwards & Abivardi, 1998).

The disappearance of a species alters the natural balance, endangers the functions of the entire ecosystem of which it is a part of, and, sooner or later, ends up affecting in one way or another our quality of life and our economy. This is why native tree species have to have special protection because they are the base of different and unique ecosystems (BBC, 2018).

Native species have been tremendously affected by human activity, by replacing them with other species imported for an economic purpose. *Pinus radiata* has been the most popular in Biscay and Gipuzkoa, and it is used for wood production due to its high and fast productivity level. This wood is mostly used by paper mills, construction activities and carpentry works (Sanchez, 2018). Wood production has affected Basque forests by changing forest ecosystems, traditional landscapes, and the qualities of the soil.

The situation of the forests is different in each province because the forest policies are under the provinces legislations. Gipuzkoa and Bizkaia have most of their forests privatized due to their forest policies, and in consequence, most of the native populations have been eliminated by individuals to develop forests plantations of conifers, which produce more and make faster money (figure 5). On the other hand, most of the forest and mountain territory in Araba is public due to the forest policies of the province, and it has helped in the conservation of native species, ecosystems, and habitats (figure 5) (Groome, 1987). The forest policies of this territory are most focused in public and community use of the forests. The privatization of the forests has the negative consequence of partially eliminating autochthonous species and ecosystems to plant species from other areas that can damage the environmental services of the forests to the society. On the other hand, there are positive impacts too, as an increase on the wood production, increase the economic value of the forests benefiting the local economy (at least in a short-medium term) and generating more jobs in forest activities and in industries related with wood products (Hodge & Adams, 2013). The authorities are trying to find a balance between the economy and the environment in the forestry sector.

In the last decade, the eucalyptus has become very popular among individuals, especially in Biscay, affecting the ecosystems of the region. It is becoming so popular because its wood production is even faster than the one of the conifers and they are more resistant to diseases (Montagu, Kearney, & Smith, 2003). The expansion of eucalypts would affect mostly conifers and *Pinus Radiata* forests because they would be replaced by them. It is a phenomenon that should be regulated by the authorities for its use because they could have negative impacts in the region. In other regions of Spain, like Galicia, eucalyptus plantations generated huge environmental problems mostly related to forest fires (Chaparro, 2018).

Apart from all of this, forests cover the 55% of the Basque Country's territory and the potential of their use for bioenergy production is high, and it could be an important part of the future energy mix of the Basque (BaskEgur, 2016). Nowadays, the wood that is being used to generate energy is the wood residue from forests, municipalities or other industries that have no other utility. Normally there are no forests that produce wood only for bioenergy purposes. This is because when wood is used for bioenergy, it generates fewer profits than if it is used on paper mills or in different wood industries (Zhang & others, 2014).

If more information about the Basque forests and its species is needed, the information can be found in the appendix.

Below, there are two maps that show the distribution of forest species in the Basque Country:

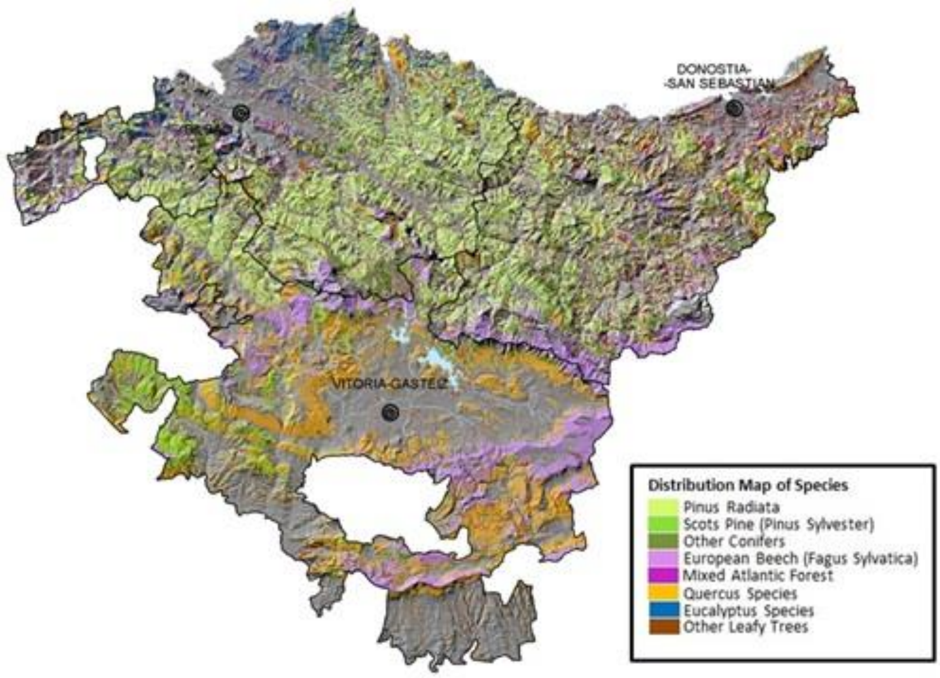


Figure 4. A map of the distribution of species in the Basque Country (Eusko Jaurlaritza, 2018).

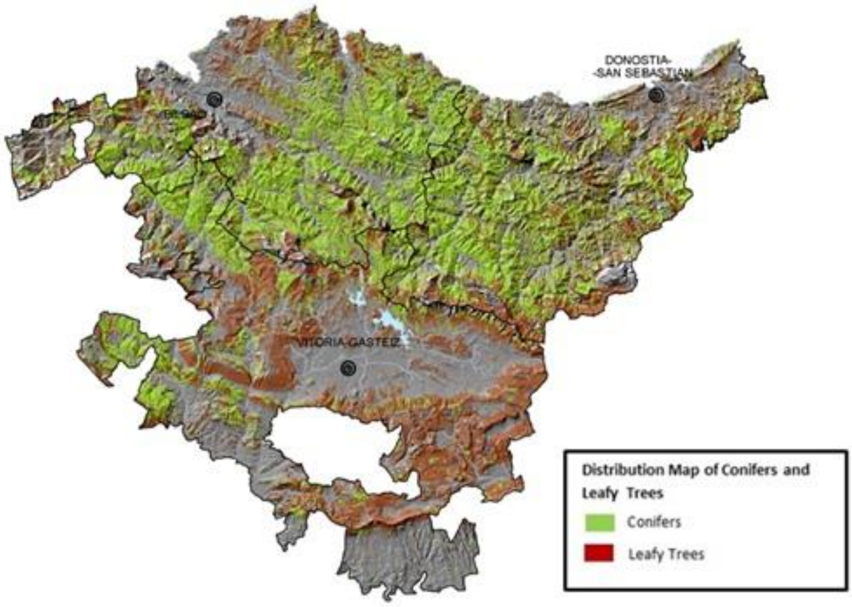


Figure 5. Distribution of conifers and leafy trees (Eusko Jaurlaritza, 2018).

2.4 Biomass and Bioenergy

Biomass is known as any organic matter that has its origin in an immediate biological process. This definition of biomass includes a whole series of products and renewable raw materials, obtained from organic matter. Biomass is mainly composed of carbohydrates, lipids, and proteins, which are in a variable proportion, depending on the nature of the biomass (Ente Vasco de la Energía, 2001, p. 8).

Bioenergy is a term for obtaining energy by different processes from organic material that comes from plants and animals. Biomass is a renewable and sustainable source of energy and can be used directly via combustion to produce heat, electricity, or indirectly after converting it. There are various forms of biofuel (PowerWorld Analysis, 2017).

Bioenergy is already a quite important renewable energy source in the Basque Country (*Figure 3*). In 2017, biomass produced 66.5% of the renewable energy for the region, but this research aims to show that the potential is higher and that it could be used for the benefit of the society and the environment. The sources that are used for bioenergy generation in the Basque Country are 4:

1. Forests for energy generation and agricultural and forest residues.
2. Animal residues.
3. Solid municipal residues and urban residual water.
4. Industrial residues.

A big part of the bioenergy generation comes from the waste incinerator called Zabalgarbi, next to Bilbao. It annually burns between 220,000 and 240,000 tonnes of municipal waste, and it generates, on average, 682 million kWh annually (Zalbagarbi, 2012). It is a discussed bioenergy source because of its potential environmental dangerousness and the doubt that municipal residues are a renewable energy source.

The Basque government and other important entities in the energy sector of the region do not share the data of biomass energy generation. As stated before, it is explained that the 66.5% of renewable energy generation comes from biomass sources, but then it is not shown from what different sources and what energy generation share each source has. This is because the Basque government wants to show that biomass energy is green and renewable and it always links the biomass to forests and wood, avoiding waste incineration, a very hot topic and criticised method in the Basque society (Barea, 2017). This makes it difficult to know how wood-based energy contributes exactly. It is estimated that the wood energy is around the 40% of the biomass energy production, it would be around the 2% of the total energy need of the Basque Country in 2017.

2.5 Woodchip Bioenergy

Woodchips are wood pieces that have been cleaned, dried and cut into small pieces. Woodchips are made from a whole-tree, logging waste, stumps, or other waste wood (Bioenergianeuvoja.fi, 2018). The processing of wood to obtain woodchips is simple, as it does not need high levels of technology, but takes time and effort. First, it is necessary to collect the wood in a sustainable way from the forests. Second, it is transported to a plant where the wood is cut into small pieces and dried (Forestry Commision England, 2017). It is usually dried naturally by the sun and air flows, to prevent expending extra energy from other energy sources. The process of drying the wood is very important because it allows the wood to have higher calorific value. In some cases, the wood can be dried entirely using industrial ovens. After this process, it has to be transported again to where it is going to be burned and used as an energy source.

In this industry, the chain process of making chips out of growing tree trunks is long, including several stages, but is quite simple in comparison with other bioenergy sources like biofuel, which requires high technology and chemical processing. The process has to be as efficient as possible, to gain energy instead of losing, because transport and the industrial process require other energy sources as oil.

Woodchips are bioenergy at its best: clean, domestic and renewable. When wood chips are dry and burned in the right way, they have an enormous energy value. They are a local resource that benefits the people and the economy of the country. Apart from this, the use and management of forests for their energetic use can be beneficial for the environment and societies. By taking the wood residue that is in the forests and the extra wood that is generated periodically, we can improve the health of the ecosystems of the forests and lower the possibility of wildfires and pests (Regos, 2016). Forest residues are those that are produced as a result of forestry activities. Forest residues come from the maintenance and improvement of the mountains and forest masses, when pruning, cleaning, etc. On the other hand, the waste resulting from cutting the trunks of trees can make wood products. Forest residues are a small part of the wood production, around 5% (Ochoa Palcios, 2014). These forests residues, residues of wood processing and municipal wood residues can be added to the wood production potential that Basque forests have to increase it.

2.6 Wood Energy in the European Union

One of the main uses of the wood has always been to supply energy. In the European Union, policy interests in energy security and renewable energy sources, combined with relatively high oil and gas prices, has led in recent years to a rethinking of the possibility of reusing wood as a source of energy. Also, the EU obliges their partners to achieve the minimum renewable energy targets: an average of the 20% of the total energy consumption for 2020. Every 5 or 10 years the targets are more ambitious. This goal is designed to help reduce emissions, improve the security of energy supply and reduce dependence on energy imports (Eurostat, 2018).

During 2005 to 2015, the consumption of biomass increased a 184% in the EU. Woodchips and other agglomerated wood products such as pellets and charcoal provided the highest share of renewable energy in the European Union in 2015, accounting for almost half (45 %) of the EU’s total renewable energy generation.

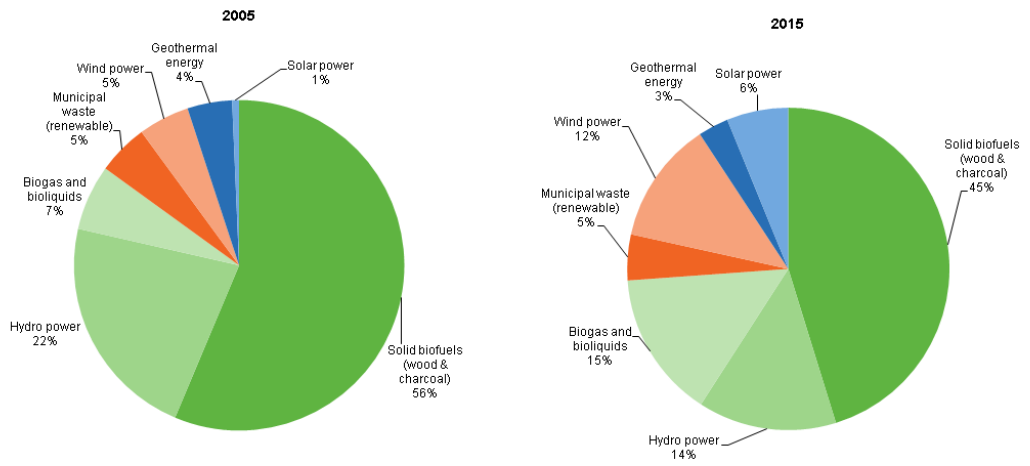


Figure 6. Gross inland consumption of renewable energy, EU-28, 2005 and 2015 (1 000 tonnes of oil equivalent) (Eurostat, 2018).

2.7 Legal Situation

In 2009, the policy framework for renewable energies was set with the renewable energy directive (Official Journal of the European Union, 2009). The directive lists biomass as a renewable energy source, and it mandates the Member States to draft National Energy Action Plans and sets conversion efficiency thresholds above with the Member States to promote bioenergy technologies.

Biomass energy generation has an advantage over fossil fuels because its Greenhouse gases emissions do not fall under the EU Emission Trading System (ETS). A study made by the International Energy Agency notes that EU ETS allowances save between 15-25 euros per tonne in CO2 taxes (European Parliament). The European Union was the first, and later the International Community agreed that the CO2 generated by biomass energy production would not be considered as an emission. The Emission Trading System of the EU is a cornerstone of the EU's policy to fight against climate change, and it is a key tool for reducing greenhouse gas emissions cost-effectively. It is the world's first and biggest carbon market.

The European Commission adopted a new forest strategy in 2013, addressing the increasing use, overall, of forests for a variety of purposes like biomass. Its objective is to regulate and ensure that all the forests in the EU are managed according to sustainable forest management principles by 2020 (European Commission, 2013).

In Spain, it is much easier to use the energy produced by wood for heating than for electricity because there is no need for the grid that complicates the bureaucracy much and it negatively impacts the investments. The companies that are in the monopoly of energy are not interested in small energy producers that can reduce their profits and the laws benefit them against small producers (Energia y Sociedad, 2016).

In the Basque Country, the use of wood to produce energy is becoming popular again, and the legislation has started to adapt and improve. Since the industrial revolutions, wood lost its popularity to fossil fuels like coal, gas, and oil. The image that wood had for its energetic use was negative as if it was for the poor. The lower energy density of the wood compared with fossil fuels had a negative impact too. Now the image of wood is changing into that of renewable energy that is beneficial for the environment and can be cheaper than conventional energy sources. Also, the Basque government developed a subsidy for wood-based energy generation individual projects in the last years that pay a percentage of the total investment of the projects. In 2017 the budget was 500,000 euros, an amount that probably will be higher in the next few years (Ente Vasco de la Energía, 2017). Most of the budget was spent on heating systems. Also, the public institution called Hazi offers different opportunities to Basque municipalities with important advantages to develop bioenergy projects (HAZI, 2018).

2.8 Sustainability and Sustainable Management of the Forests

Sustainability is a concept that is based on the management of resources, like forests, where they can last for the generations to come. This concept has three main pillars that are the environment, the economy, and society that need to be in balance (Beattie, 2018). Sustainability aims to make the resources renewable or circular by taking care of natural processes and the environment, or reusing and recycling them. Sustainable forestry is defined as the use of forest products, like wood, in a way the forest's and their ecosystems are minimally affected (Rainforest Alliance, 2016).

The sustainable management of forest resources, and biomass, in general, is the key to being a renewable resource, but the specifications of what is sustainable and what isn’t are not clear (European Commission, 2010).

This research understands that the sustainability of the Basque forests is directly linked with the protection of native forests. The environmental benefits that they give to the environment and society are of high relevance. These forests can be used if it is sustainably and without affecting them negatively. The research understands that conifers and eucalyptus plantations are forests that have a very low environmental relevance and that in consequence they can be used intensively for wood production. The key for a sustainable forest use is to find the balance between native species and species that are used in economic activities, understanding that both are important for the economy, environment, and society of the region.

The overexploitation of the forests is a problem that could occur if the forests are too intensively used and the principles of sustainability are not respected. The overuse of the forests could generate a loss of ecosystems and ecosystemic values (Rehnus, Nazarek, Mamadzhanov, Venglovsky, & Sorg, 2013) .

CHAPTER 3 RESEARCH DESIGN

The research design explains how this research has been done.

3.1 Research Question

The research question is the basis to start the research project. The research is based on the main question below.

Main Research Question

What is the annual wood biomass potential of the Basque forests, and the annual energy potential of the wood biomass, while respecting native species?

3.2 Research Material and Accessing Method

3.2.1 Required Data and Information

The use of questions and answers will determine the data needed for this research project. They are shown in the table below:

No.	Research Questions	Required Data to Answer the Question
1	What is the current forest situation in the Basque Country?	Land use and forest data are needed. The main Tree species have to be known.
2	How are the forests used nowadays?	It's economic, social and environmental use.
3	Who owns them?	Ownership map and data. This will condition the availability of them.
4	Are some forests not allowed to be used for this practice?	Protected areas, protected species.
5	What is the use of the forests to get energy nowadays?	The data of the total use in the present is needed to know to what point this use can be increased. Energy annual reports.

Table 3. Required data and information

3.2.2. Source and Method of Data Collection

No.	Data/information required to answer the questions	Data/information	Source of Data	Method of Accessing Data
1	Forest situation	Land use, ownership, Species	Basque Government	Literature review
2	Productivity of tree species	Biomass production each year, the age of the trees, the density of forests	Forestry Department	Literature review
3	Different bioenergy sources and their percentage in energy generation	How much is exactly the portion of the energy generated by wood?	Energy Department, annual energy reports	Literature review
4	Data about which are sustainable practices and which not	A document with specific considerations about the sustainability level of bioenergy practices	European Union	Literature review
5	Other projects in the Basque Country working with this energy source	Projects that work as an Example	Municipalities, small companies, individuals	Literature review, interview

Table 4. Source and method of data collection

3.3 Research Methodology

An adequate and clear methodology to calculate the potential that current Basque forests have for its use as bioenergy sources will be the primary point of the research. The methodology has been developed using different information, sources, and methods. Information about the Basque forests is from the forest inventory of the Basque government (Inventario forestall, 2017). The data is available in table 2.

The potential that Basque forests have to be used as a bioenergy source while respecting native forests refers to the maximum capacity that these forests have to produce as much as possible wood for its energetic use in a sustainable way. In the research, it will be assumed that all the forests are being used for biomass production. The potential will be calculated in tonnes and later in MJ. The area of the forests will only be in hectares. All the wood that will be theoretically produced will be used for energy generation purposes like heating or electricity generation. Other economic activities that wood can have will not be considered.

The methodology has 6 different steps:

1. Tree species that have less than 1,000 hectares of area will not be considered in the research. Most of these species are widely spread in the territory which makes their use as an energy source difficult. Also, because of their scarcity and landscaping value in the region, their protection is more important (Halkka & Lappalainen, 2001).

Species out of the Calculation < 1,000 Hectares

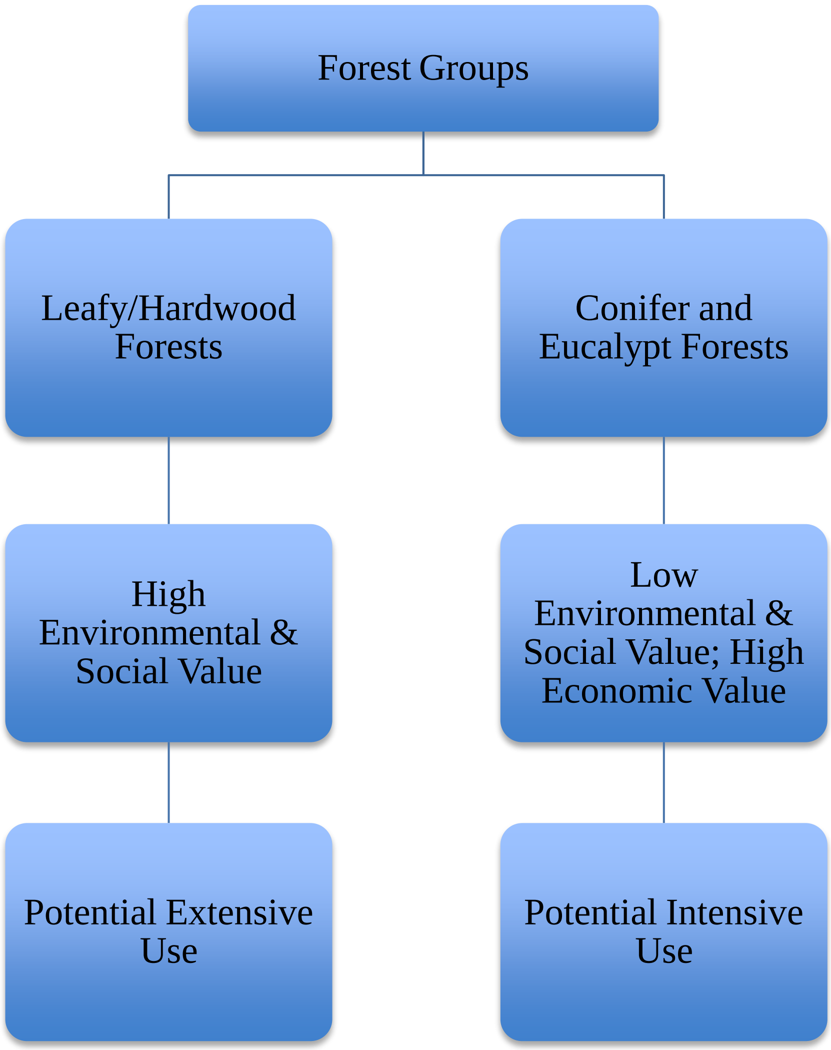
2. The effect that protected nature areas could have on the calculation of the potential will be considered. The protected nature areas could be restrictive, in some cases, to do an extractive use of the forests. If nature protected areas limit some forests use, they will be removed from the calculation of the potential.

Completely Protected Forests = Out of the Calculation

3. The forests will be divided into two groups due to their different biological cycles, ecosystem importance, wood productivity and economic use. Leafy or Hardwood forests will be one group and Conifers and Eucalyptus forests will be the other. These two groups should be used differently for this research.

   Leafy or hardwood forests will be used extensively. Extensive forestry can be defined as the practice of forestry by low operating and investment cost for the area to achieve medium-low wood production levels (Benson, 1990). In extensive uses of forests, autochthonous species are customarily used to produce wood. The extensive use of the forests do not only value the wood production, but it also values other important services that these forests give like ecosystem protection, public utility, water services, avoiding soil erosion and acidification, and improving soil fertility or landscape value (Pagiola, 2004). The extensive use of the forests produces less wood compared with the intensive forest use, but it is much more sustainable, and it is based on respecting the forests and their species (Nadeau Fortin, Sirois, & St-Laurent, 2016).

On the other hand, Conifers and Eucalypts forests will be used intensively. Intensive Forest use can be defined as the practice of forestry by medium-high operation and investment cost for each hectare to achieve high levels of wood production in the shortest time as possible (Benson, 1990). The goal is the concurrent management of all forest values to produce an optimum balance of quantity and quality of desired forest products over a minimum of time. In intensive forests, other values of the forests like biodiversity, autochthonous species, fauna, landscape value or soil fertility, and others are not relevant. Intensive forest uses are often based on monocultures of the same species in big extensions of territory that are not sustainable, at least in large quantities (Poudel & others, 2011).



Scheme 1. Different forest groups

4. Each tree species forest will be divided into four different states of mass (age): cut forests, young forests, medium-age forests, and adult forests (Table 2). Each state of mass will have a different wood production for each hectare of the species per year (Euskadi.eus, 2004). The species from the group of conifers and eucalypts will have a higher wood production than the group of hardwood species. The research estimates that conifers and eucalypts forests will have a maximum wood production of 30 tonnes per year and per hectare, and hardwood forests will have 6 tonnes per year and hectare in grown, and high-density forests (Observatorio de la Madera, 2010). The wood production of adult forests

with high-density levels will be the base data. Medium-age forests will have half of the wood production potential that adult forests have, and young forests will have a quarter of the wood production potential that medium-age forests have (Verkerk, et al., 2015). Cut forests will not be able to produce anything in the near future. As a result, they will not have any wood production.

Wood Production Potential in Each State of Mass		Hectares needed for the same wood production as one adult forest hectare
Cut Forests	0	No production
Young Forests	12.5%	8
Medium-age Forests	50%	2
Adult Forests	100%	1

Table 5. Wood production potential in each state of mass of the forests

Below there are two examples of how the calculation will be done with a tree species of each group: *Fagus sylvatica* (hardwood group) and *Pinus nigra* (conifers and eucalypts group). The numbers in table 2 are taken from the forest inventory made by the Basque government in 2017. These calculations are done on each forest species. To make the calculation of the potential wood production that differently aged forests have, it is supposed that all the forest have a high density. After this step, the density's effect will be considered.

Wood Production of *Fagus Sylvatica* (Hardwoods Group)			
Forest Age Group	Hectares	Tonnes per Hectare	Total Tonnes per Year
Cut Forests	13	0	0
Young Forests	1,886	0.75	1,414
Medium-Age Forests	4,276	3	12,828
Adult Forests	48,443	6	290,658
Total	54,619	–	304,900

Table 6. Calculation of the wood production potential of *Fagus Sylvatica*

Wood Production of *Pinus Nigra* (Conifers & Eucalypts Group)			
Forest Age Group	Hectares	Tonnes per Hectare	Total Tonnes per Year
Cut Forests	129	0	0
Young Forests	770	3.75	2,887
Medium-Age Forests	2,198	15	32,970
Adult Forests	10,788	30	323,640
Total	13,885	–	359,497

Table 7. Calculation of the wood production potential of *Pinus*

5. All the wood production potential from the different species, considering the different ages of the forests, will be added in the correspondent forest group depending on each species. This wood production potential has been calculated assuming that all forests had a high density. In this step, the total wood production potential of each forest species will be manipulated depending on the density that these forests have. The density refers to the proportion of the forest covered area per hectare (Euskadi.eus, 2004). The density of the forests will change the potential that each forest has. If the density level is high, the potential will not be changed. Forests that have medium density will have half of the

wood production that high-density forests have, and forests with low density will have a quarter of the wood production that high-density forests have.

Wood Production Potential in Each Forest Density Level		Hectares Equivalent to Wood Production of a High-Density Forest Hectare
Low Density	25%	4
Medium Density	50%	2
High Density	100%	1

Table 8. Wood production potential in each forest density level

Combining the state of mass (age) and the density of the forests, the wood production potential that each forest kind would have would be this:

State of Mass (Age)

Cuts	Young	Medium	Grown	DENSITY
0	3.13%	12.5%	25%	Low
0	6.25%	25%	50%	Medium
0	12.5%	50%	100%	High

Table 9. Wood production potential in different forests

Below there are two examples of how the different densities affect the wood production potential, with a tree species of each group: *Fagus sylvatica* (hardwood group) and *Pinus nigra* (conifers and eucalypts group). The numbers in Table 2 are taken from the forest inventory made by the Basque government in 2017. These calculations are done on each forest species.

Wood Production of *Fagus Sylvatica* (Hardwoods Group)				
Density	Hectares	Average Wood Production in High-Density Forests (Tonnes/Year/Hectare)	Wood Production Potential	Total Tonnes per Year
Low	1,156	5.58	25%	1156×5.59×0.25 =1612
Medium	3,713	5.58	50%	3,713×5.58×0.5 =10,359
High	49,350	5.58	100%	49,350×5.58 =275,373
Total	54,619	–	–	287,344

Table 10. Wood production potential of *Fagus Sylvatica* considering differently aged forests and density levels

Wood Production of *Pinus Nigra* (Conifers & Eucalypts Group)				
Density	Hectares	Average Wood Production in High-Density Forests (Tonnes/Year/Hectare)	Wood Production Potential	Total Tonnes per Year
Low	1,853	25.9	25%	1,853×25.9×0.25 =11,998
Medium	5,582	25.9	50%	5,582×25.9×0.5 =72,287
High	6,450	25.9	100%	167,055×25.9 =167,055
Total	13,885	–	–	251,340

Table 11. Wood production potential of *Pinus Nigra* considering different age forests and density levels

6. After this, the potential that Basque forests have to be a source for bioenergy production will be calculated adding the potential of all the forest species (considering different age and density levels). At first, the potential will be calculated in tonnes of wood per year. To conclude, these wood tonnes will be converted into the potential MJ per year.

   To calculate the energy potential that Basque forests have while respecting native species, it is necessary to multiply the tonnes of wood available each year by the calorific value of the wood. The calorific value of a fuel expresses the amount of energy released during the complete combustion of a unit of mass of the fuel (Atalaya, 1991). One of the biggest problems to calculate the calorific value of wood is the moisture or water content of it. It changes the calorific value of the fuel by reducing it. Indeed, a part of the energy released during the combustion process is spent in the evaporation of the water and, consequently, is not available for any thermal use (Günther, Gebauer, Barkowski, Rosenthal, & Bues, 2012). There are two different calorific values that fuels have:

   - Gross calorific value: It indicates how much energy can be released during the complete combustion of a given amount of fuel considering that there is not any water (Marquard & Bahls, 2018).
   - Net calorific value: It indicates how much energy can be released during the complete combustion of a given amount of fuel considering that some energy is lost due to the water content of the fuel. The net calorific value of wood will be used in this research. It is assumed that wood will always have a percentage of humidity.

$$\text{Gross Calorific Value} = \text{Net Calorific Value} + \text{Condensation Heat}$$

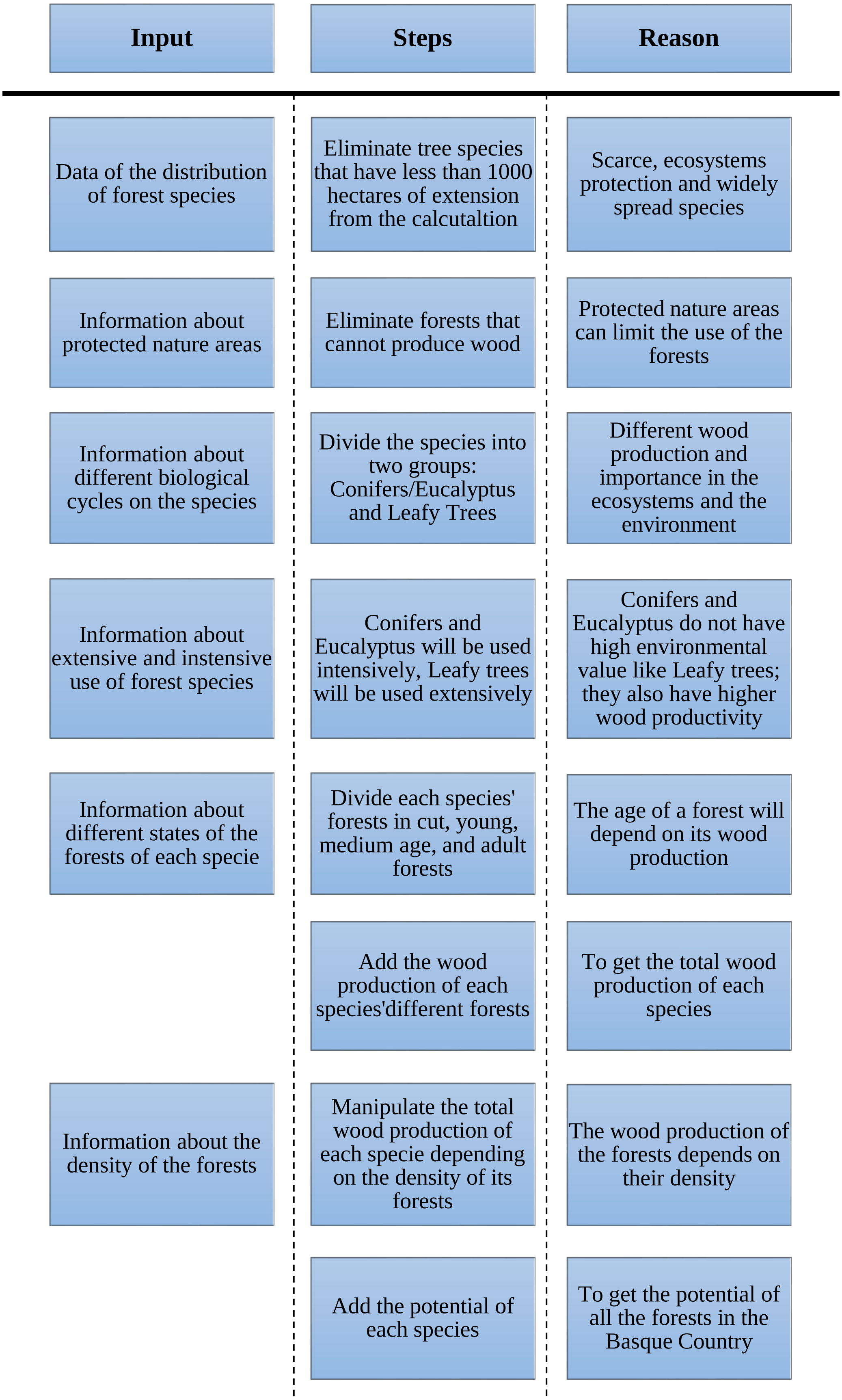
Formula 1. Gross calorific value

Last, defining the process and the technology of the combustion that will be used to calculate the potential is needed. There are several processes that have different energy efficiency levels that will affect the potential (Mckendry, 2002). This research estimates that the best way for wood to generate energy is by combustion that generates heat. This heat could be mostly used for heating and industrial processes. Processes that generate electricity from wood have less energy efficiency and more energy losses. The access to the electricity grid could also complicate the bureaucracy and increase costs, especially in Spain. In conclusion, to calculate the energy that wood potentially could generate, this formula will be used:

$$\text{Wood Tonnes} \times \text{Net Calorific Value of Wood} \times \text{Energy Efficiency}$$

Formula 2. To calculate the energy that wood can generate

Below there is a scheme that explains the methodology of the research in a short way:



Scheme 2. Methodology to calculate the forest potential

3.4 Research Strategy

The research strategy is based on getting as much information and data as possible about the current situation of Basque forests and forestry in general. It is a research-based on bibliography review. The research is mostly theoretically based.

The research strategy is mostly quantitative because it will be based on numbers, as the total potential of the Basque forests to be a bioenergy source. The qualitative part will be focused on the specific requirements and criteria to get the wood from the forests. The sustainability of this process and the methods will be considered as quality.

3.4.1 Research Boundary

Research boundaries are used to determine the consistency and limitations of the research. This research aims to be as specific and correct as possible, but it has to be taken into account that for a proper and very realistic appreciation of the forest potential for its energy use, much time and more personnel are needed. These are the biggest obstacles that will be found in the research project:

- The data collection is limited. Being a part of public institutions would help in getting more and better information. Each forest has different conditions and biomass.
- The number of people researching (1) and the available time frame is limited, as a result, it will limit the research.
- The GIS (Geographic Information System Software) program used in the project will be QGIS, a free version of ArcGIS not as good. It adds limitations.

3.5 Defining Concepts

To have a proper understanding of all the concepts in the document, a few will be defined below:

Biomass: The biological material derived from living, or recently living organisms.

Bioenergy: The energy which is stored in biological matter or biomass. This can be anything from plants, straw, slurry, food waste, and even sewage. Bioenergy consists of creating energy from biomass, normally by combustion.

Fossil fuel: Fossil fuels are hydrocarbons, primarily coal, fuel oil or natural gas, formed from the remains of dead plants and animals. They are originally biomass products.

Woodchips: Small-mid sized solid material made by cutting larger pieces of wood. They can be used as a solid biomass fuel.

Primary Energy Consumption: The direct use at the source, or supply to users without transformation, of crude energy, that is, the energy that has not been subjected to any conversion or transformation process.

EU Emissions Trading System: A cornerstone of the EU's policy to combat climate change and it is a key tool for reducing greenhouse gas emissions cost-effectively. It is the world's first major carbon market and remains the biggest one.

CHAPTER 4 CALCULATION OF THE POTENTIAL

The potential that Basque forests have to be a renewable source of bioenergy while respecting native species will be calculated in different steps, as it is explained in the research methodology.

4.1 Elimination of Inadequate Species (Step 1)

Species that have less than 1,000 hectares of forest area will be eliminated from the calculation of the potential. These species normally appear very scattered, making their exploitation very difficult and not economically profitable (Baffetta, Corona, & Fattorini, 2011). Also, they are species that have a significant environmental and landscape value that has to be preserved. We can find different ecosystems that rely on these scattered tree species that have some endangered species mixed in. For example, different species that are endangered or rare as *Sorbus Latifolia, Ilex aquifolium, Osmunda Regalis L.*, etc., partially depend on *Betula spp, Alnus glutinosa or Fraxinus spp* (Euskadi.eus, 2006).

There will be only one exception; the group called other Eucalyptus in table 2 will be considered in the calculation, despite having less than 1,000 hectares of extension. Eucalypts are not native in the Basque Country, and they are used in the forestry activity to produce wood. Eucalypts species are monocultures that are not scattered and do not have almost any environmental value. They can easily be used as a wood source for energy generation. These Eucalypts have very similar characteristics with *Eucalyptus globulus* and *Eucalyptus nitens.*

Of all the species found in table 2, these will not be included for the calculation of potential:

1. *Pinus halepensis* (Alepo pine), 798 hectares.
2. *Picea abies* (Norway spruce), 554 hectares.
3. *Quercus petraea* (Sessile oak), 674 hectares.
4. *Alnus glutinosa* (Common alder), 811 hectares.
5. *Salix spp.* (Willow), 194 hectares.
6. *Robinia pseudacacia* (Black locust), 977 hectares.
7. *Platanus spp.* (London plane), 294 hectares.
8. *Populus alba* (White poplar), 397 hectares.
9. *Populus nigra* (Black poplar), 109 hectares.
10. *Betula spp.* (Silver birch), 647 hectares.
11. *Fraxinus spp.* (European ash), 824 hectares.
12. A mixed forest of cliff (423 hectares)

In total 6,702 hectares of forests are not used in the research, 1.68% of all the forests of the Basque Country.

4.2 Protected Nature Areas (Step 2)

There is another factor that has to be considered about Basque forests, protected nature areas. Protected nature areas can be, in some cases, an obstacle for the use of the forests that are inside their jurisdiction for wood extraction purposes. These protected nature areas are under the law 16/1994, modified in 2010, to protect the nature in the Basque Country and is divided into four different protected areas: nature parks, protected biotopes, special trees, and Natura 2000 areas (Eusko Jaurlaritza, 2013). They cover the 20.3% of the Basque territory (Eusko Jaurlaritza, 2015).

There also is a biosphere reserve declared by UNESCO in 1984 that can affect the activity in some forests.

4.2.1 Nature Parks

Nature parks are places where human presence has not or has minimally affected or changed the autochthonous environment. It distinguishes the beauty of the sight and the evocative nature of the ecosystems, the extraordinary geomorphological formations, vegetation, and fauna (BOE, 2014). There are 9 in the Basque Country. The public authorities need priority action channels to be able to combine two purposes: the use of natural resources and public use, and saving or re-establishing ecological, aesthetic or educational values (Euskadi.eus).

The use of the forests for wood production is permitted under some regulations that aim to protect these areas and ecosystems. Most of the forest uses will have to be extensive, respecting the ecosystems and damaging them as little as possible.

4.2.2 Protected Biotopes

The protected biotopes have been created to protect ecosystems, communities, biological elements, geological sites with interest, and natural spaces in the natural environment, which are unique, fragile, particularly beautiful, or of outstanding scientific interest, worthy of extraordinary appreciation (Euskadi.eus). Eight protected biotopes can be found in the region.

The exploitation of resources will be restricted in biotopes, except if the values can be protected and the same exploitation can be achieved. Extensive use of forests could be a solution.

4.2.3 Special Trees

Special trees, due to their unusual or prominent characteristics (size, age, history, beauty, location, etc.) are called tree specimens that deserve special protection (BOE, 2014). These trees cannot be touched. 25 trees are protected in total, an insignificant value for the research.

4.2.4 Natura 2000 Areas

Natura 2000 is a network of core breeding and resting sites for rare and threatened species and some rare natural habitat types, which are protected, in their own right. The Natura 2000 areas were created by the European Union. It stretches across all 28 EU countries, both on land and at sea. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats (Ec.europa.eu, 2017). Natura 2000 is a system of short nature reserves where human activities are allowed in most of the areas.

The majority of Natura 2000 areas with forests are located inside nature parks, and protected biotopes and other areas are focused on rivers and wetlands. Due to this situation, Natura 2000 areas do not have a considerable impact on the research.

4.2.5 Biosphere Reserve

Biosphere reserves are areas comprising terrestrial, marine, and coastal ecosystems. Each reserve promotes solutions reconciling the conservation of biodiversity with its sustainable use (UNESCO). The most important areas respecting to biodiversity protection are restricted to use, but these areas are quite small inside the biosphere reserve, and it is more focused on river and coastal zones than forests. Most of the forest can be used intensively or extensively.

4.2.6 Effect of Protected Nature Areas on the Forests Potential Calculation

In most of the protected nature areas, the use of the forests with the purpose of wood production is not restricted. They have limitations, and the forests and ecosystems have to be respected. The areas where the use of the forests is completely restricted are quite limited inside the protected nature areas and to know their location, the area they cover, and the species that they contain with their forest age and density level is very difficult because all this information is not available. The research understands that without this information it is not possible to calculate the effect that protected nature areas have in the calculation of the forest potential.

The positive thing for the research is that the majority of these areas are formed by autoctonous species that were already planned to be extensively used in the methodology, a thing that is possible in the protected areas. This minimizes the effect that protected nature areas have in the calculation.

In conclusion, protected nature areas are not going to condition the potential of the Basque forests to be a source of bioenergy in this research, although they should be considered. This should be studied by the authorities or other research. The effect of the protected nature areas is not considered in the calculation of the potential and has to be taken into account in the conclusion of the research.

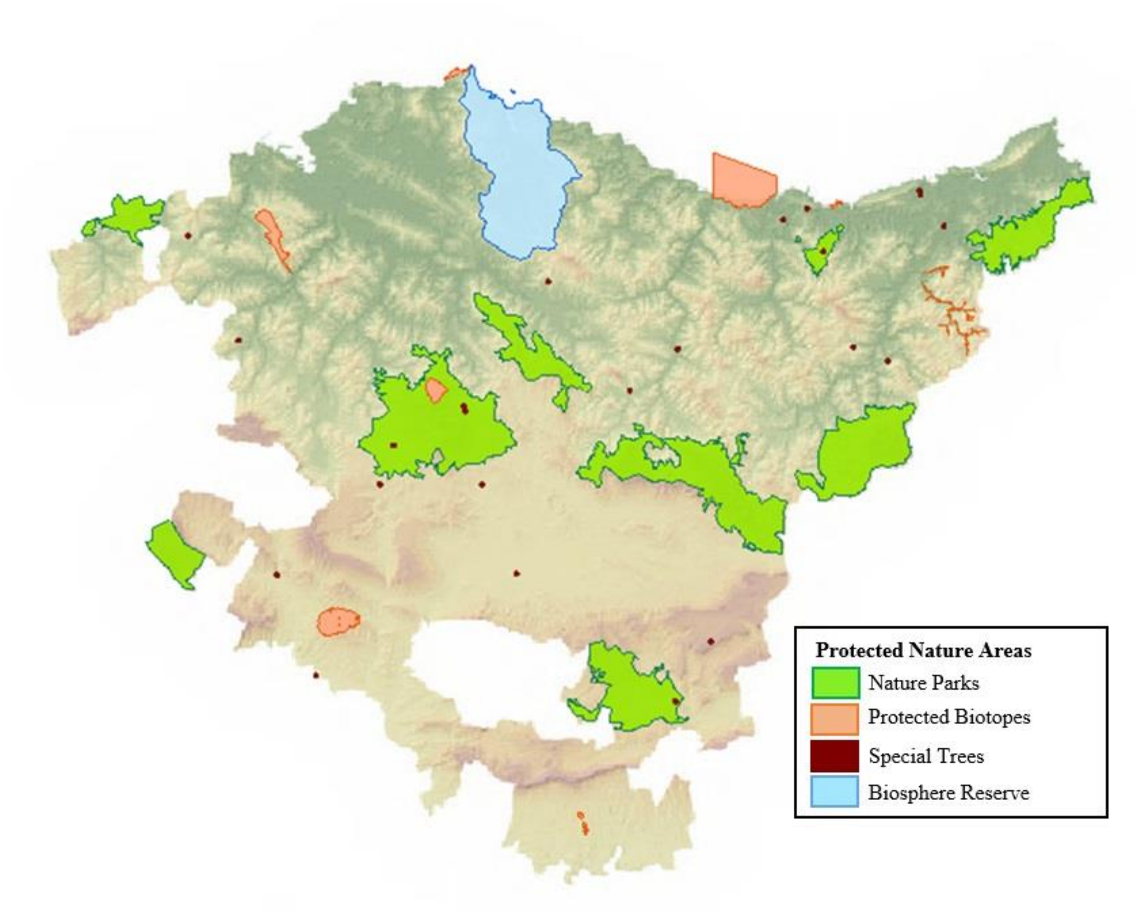


Figure 7. Protected nature areas in the Basque Country (GeoEuskadi, 2018).

4.3 Extensive and Intensive Forest Uses (Step 3)

In the research, these two forest uses or management models are going to be used depending on the characteristics of each forest group. The two forest uses or management models are the most used worldwide, although there are more that are not going to be considered due to the extra complication that they can generate for the research (AgriInfo.in, 2015).

4.3.3 Tree Species in Extensive and Intensive Forest Use

To calculate the potential, the tree species of the Basque Country will be divided into two groups as explained before in the methodology. The group of hardwood species will be managed extensively, and the group of conifers and eucalypts intensively.

The decision of using some forests extensively and others intensively has been done depending on the origin of the tree, its ecological value, landscape value, wood production level, and other environmental services that the forests give to the environment and the society (Benson, 1988).

4.3.3.1 Hardwood Forest Species

Trees that should be managed extensively, depending on the criteria of the research, are tree species that are autochthonous, have medium or high ecological value, have landscape value, have a medium-low wood production level, and give different environmental services to the environment and the society. Hardwood species fulfill these requirements.

Below are the tree species that enter in this group:

1. *Quercus robur* (Common oak) 15,924 hectares.
2. *Quercus pyrenaica* (Pyrenean oak) 13,110 hectares.
3. *Quercus faginea* (Valencian oak) 26,665 hectares.
4. *Quercus ilex* (Evergreen oak) 26,364 hectares.
5. Riverbank forests 4,547 hectares.
6. Leafy plantations 3,610 hectares.
7. *Quercus rubra* (Northern red oak) 3,907 hectares.
8. *Fagus sylvatica* (European beech) 54,619 hectares.
9. *Castanea sativa* (Sweet chestnut) 1,163 hectares.
10. Atlantic mixed forest 35,414 hectares.
11. Other leafy 3,767 hectares.

In total 189,090 hectares can be managed extensively depending on the research, the 47.6% of all the forests. Adding the percentage of the 1.68% of the forests that are not going to be used, 49.3%. This percentage explains that half of the forests will be managed while respecting the forests.

4.3.3.2 Conifers and Eucalypts Forest Species

Tree species that should be managed intensively, depending on the criteria of the research, are trees that are not autochthonous, have low or none ecological value, do not have landscape value, high wood production level, and do not give most of the environmental services that autochthonous forest do. Conifers and eucalypts fulfill these requirements.

Below are the tree species that enter in this group:

1. *Pinus sylvestris* (Scots pine) 17,511 hectares.
2. *Pinus nigra* (Black pine) 13,885 hectares.
3. *Pinus pinaster* (Maritime pine) 6,768 hectares.
4. *Pinus radiata* (Radiata pine) 123,921 hectares.
5. *Pseudotsuga menziesii* (Oregon pine) 7,360 hectares.
6. *Larix* species 7,915 hectares.
7. *Chamaecyparis lawsoniana* (Lawson cypress) 3,297 hectares.
8. Other conifers 2,581 hectares.
9. *Eucalyptus globulus* (Tasmanian bluegum) 10,894 hectares.
10. *Eucalyptus nitens* (Shining gum) 6,355 hectares.
11. Other eucalyptus 945 hectares.

In total 201,432 hectares can be managed intensively depending on the research; 50.7% of all the forests. Most of these forests are currently being intensively used for wood production purposes like paper, furniture, and other types of industries, which are very important for the local economy. It is estimated that the sector generates 13,000 direct jobs and 7,000 indirect jobs in the Basque region (BaskEgur, 2015).

4.4 Wood Extraction of the Forests

Every year wood has to be extracted from the forests to use it as an energy source and meet the energy needs of the society. The wood quantity that will be extracted from each forest will depend on the tree species, the type of use of the forests (extensive or intensive), the state of mass (age) and the density of the forests:

- Depending on the tree species, the use of the forests will be different and also the amount of extracted wood.
- The state of mass of the forests (the age) will condition the quantity of the wood that can be extracted.
- The density of trees of a forest will condition the quantity of wood that can be extracted.

The research bases its original data of wood extraction in 6 tonnes per hectare and year in forests of extensive use that are adult or grown and have a high density (Boyle, Tappeiner, Waring, & Smith, 2016). In the case of intensive use forests, the original data for wood extraction is 30 tonnes per hectare and year in adult forests with a high density (Observatorio de la Madera, 2010).

4.4.1 The State of the Mass in Hardwood Forests (Step 4)

First, the state of mass or age of the forests is going to be considered. The data appears in table 2. All the forests that are going to be used extensively will be divided into 4 groups as explained before in the methodology: cut forests, young forests, medium-age forests, and adult forests.

1. Cut forests: Forests that have been cut and replanted. In consequence, they can not produce any wood in the near future. It ranges from the germination of the

saplings until they reach 25 cm in height. It assumes the phase of installation of new mass (Aula Silvicultura, 2008).They represent 341 hectares, the 0.18% of hardwood forests (*Table 2*).

2. Young forests: Trees from 25 cm high too until they begin their natural pruning processes. These forests do not have large biomass amounts and cannot be used in excess, or the future adult forests they become will be in danger (Constanzo, 2016). Young forests represent 13,810 hectares, the 7.3% of hardwood forests (*Table 2*). If all the young forests would have a high density, they could produce 10,357.5 tonnes of wood every year. The wood production would be of 0.75 tonnes per hectare per year (*Table 12*).
3. Medium-age forests: Trees that begin their natural pruning processes to trees that have an average of 20 cm of normal diameter (Aula Silvicultura, 2010). They represent 81,823 hectares, the 43.27% of hardwood forests (*Table 2*). If all the medium-age forests would have a high density, they could produce 245,469 tonnes of wood every year. The wood production would be of 3 tonnes per hectare per year (*Table 12*).
4. Adult forests: Forests where its trees have, on average, larger normal diameters than 20cm (Aula Silvicultura, 2008). Adult forests represent 93,116 hectares, the 49.24% of hardwood forests (*Table 2*). If all the adult forests would have a high density, they could produce 558,696 tonnes of wood every year. The wood production would be of 6 tonnes per hectare per year (*Table 12*).

Below, is a table that explains in what quantity the wood will be extracted from the different hardwood forest types, in respect to their state of mass (age) and density.

State of Mass (Age)

Cuts	Young	Medium	Adult		
0	0.187	0.75	1.5	Low	**DENSITY**
0	0.375	1.5	3	Medium	
0	0.75	3	6	High	

Table 12. Wood extraction values in different hardwood forests (tonne/year)

In total, if all hardwood forests would have a high density, the wood production potential per year could be of 814,522 tonnes. On average, for every hardwood forest hectare, the wood production would be of 4.31 tonnes per year.

4.4.2 The Density of Trees in Hardwood Forests (Step 5)

Density is a reliable indicator of the degree of occupation of a specific time and place by trees; besides, it is one of the few variables that represent the structure of forests in a simple, objective manner (Ramos, et al., 2018). Depending on the density of the forests the wood production will be different. There are 3 different density levels: low, medium, and high:

1. Low density: When an area is covered by trees in a percentage of 39% or lower (Euskadi.eus, 2004). They represent 16,977 hectares and the 8.98% of all hardwood forests (*Table 2*). Low-density hardwood forests could be able to produce 18,286 tonnes of wood every year (*Table 13*).
2. Medium density: When an area is covered by trees between a percentage of 40% and 69% (Euskadi.eus, 2004). They represent 33,654 hectares and the 17.8% of

hardwood forests (*Table 2*). Medium density hardwood forests have the capability to produce 72,493 tonnes of wood every year (*Table 13*).

3. High density: When an area is covered by trees in a percentage of 70% or higher (Euskadi.eus, 2004). They represent 138,090 hectares and the 73.22% of hardwood forests (*Table 2*). High-density extensive forests could be able to produce 596,393.4 tonnes of wood every year (*Table 13*).

How the calculations are done is shown in the table below.

Wood Production Potential of Hardwood Forests				
Density	Hectares	Average Wood Production in High-Density Forests (Tonnes/Year/Hectare)	Wood Production Potential	Total Tonnes per Year
Low	16,977	4.31	25%	16,977×4.31×0.25 =18,286
Medium	33,654	4.31	50%	33,654×4.31×0.5 =72,493
High	138,090	4.31	100%	138,090×4.31 =596,393
Total	188,721	–	–	687,172

Table 13. Wood Production Potential of Hardwood Forests

Applying the methodology of this research and using *Table 12* with the wood extraction values of different hardwood forests, the density of the forests changes the wood production potential. Due to the majority of hardwood forests having high density, the wood production potential of hardwood forests did not lower much and is 687,172.4 tonnes per year.

4.4.3 State of Mass in Conifers and Eucalypts Forests (Step 4)

All the tree species that are in the conifers and eucalypts group will be divided into four groups as explained before in the methodology: cut forests, young forests, medium-age forests, and adult forests.

1. Cut forests: They represent 8,211 hectares and the 4.07% of the conifers and eucalypts forests (*Table 2*). These forests cannot produce any wood.
2. Young forests: They represent 25,571 hectares and the 12.7% of the conifers and eucalypts forests (*Table 2*). If all the young forests would have a high density, they could produce 95,891 tonnes of wood every year.
3. Medium-age forests: They represent 26,572 hectares and the 13.2% of the conifers and eucalypts forests (*Table 2*). If all the medium-age forests would have a high density, they could produce 398,580 tonnes of wood every year.
4. Adult forests: They represent 141,078 hectares and the 70% of the conifers and eucalypts forests. If all the adult forests would have a high density, they could produce 4,232,340 tonnes of wood every year.

Tonnes of wood extraction per year and hectare in intensive forests:

State of Mass (Age)

Cuts	Young	Medium	Adult	DENSITY
0	0.94	3.75	7.5	Low
0	1.875	7.5	15	Medium
0	3.75	15	30	High

Table 14. Wood extraction values in different intensive forests

In total, if all intensive forests would have a high density, the wood production could be 4,726,811 tonnes every year. On average, for every conifer or eucalyptus forest hectare, the wood production would be of 23.47 tonnes per year

4.4.4 The Density of Trees in Intensive Forests (Step 5)

There are 3 different density levels in this research:

1. Low density: They represent 43,303 hectares and the 21.5% of conifers and eucalypts forests (*Table 2*). Low-density conifer and eucalypt forests could be able to produce 254,080 tonnes of wood every year (*Table 14*).
2. Medium density: They represent 64,145 hectares and the 31.84% of conifers and eucalypts forests (*Table 2*). Medium density conifer and eucalypt forests could be able to produce 752,741 tonnes of wood every year (*Table 14*).
3. High density: They represent 93,984 hectares and 46.66% of conifers and eucalypts forests (*Table 2*). High-density conifer and eucalypt forests could be able to produce 2,205,804 tonnes of wood every year (*Table 14*).

How the calculations are done is shown in the table below.

Wood Production Potential of Conifers and Eucalypts Forests				
Density	Hectares	Average Wood Production in High-Density Forests (Tonnes/Year/Hectare)	Wood Production Potential	Total Tonnes per Year
Low	43,303	23.47	25%	43,303×23.47×0.25 =254,080
Medium	64,145	23.47	50%	64,145×23.47×0.5 =752,741
High	93,984	23.47	100%	93,984×23.47 =2,205,804
Total	201,432	–	–	3,212,625

Table 15. Wood production potential of conifers and eucalypts forests

Applying the methodology of this research and using *Table 13* with the wood extraction values of different conifer and eucalypts forests, the density of the forests changes the wood production potential. Due to the fact that only half of the forests have high density, the wood production potential of intensive forests lowers considerably to 3,212,625 tonnes per year.

4.4.5 Total Wood Extraction Potential

Once calculated the potential that hardwood forests and conifers and eucalypts forests have, it is possible to get the total potential. As explained before, the potential has been calculated depending on the tree species, forest management or use type, forest state of mass or age, and their density.

On the one hand, hardwood forests in their current situation have the potential to produce 687,172 tons of wood per year that can be used for energy generation purposes, while respecting native species. On the other hand, conifers and eucalypts forests in their current situation have the potential to produce 3,212,625 tonnes of wood per year.

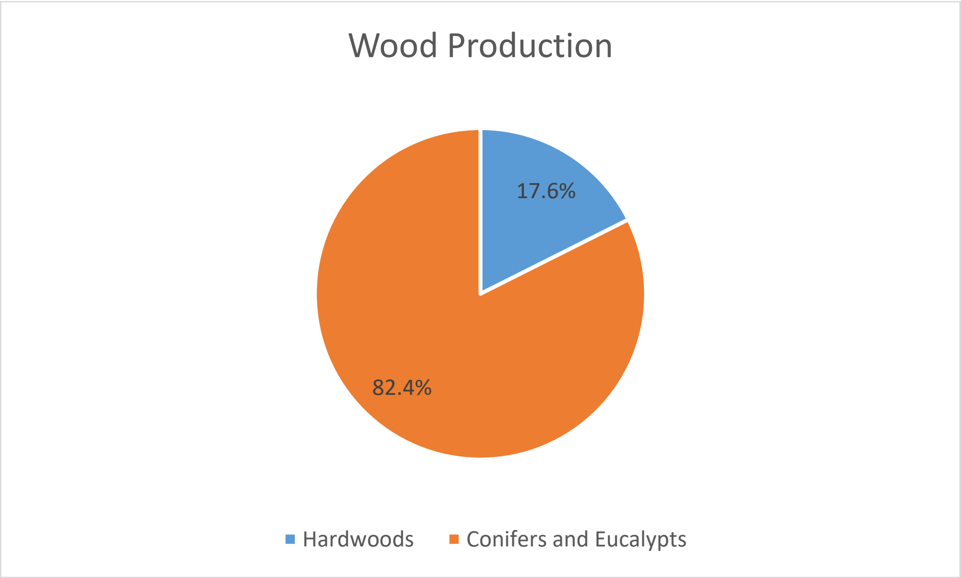


Figure 8. Wood production share of each forest group

In conclusion, this research estimates that Basque forests have the potential to annually generate 3,899,797 tonnes of wood in a way that respects autochthonous species.

4.5 The Energy Potential of Basque Forests

The gross calorific value of wood of different species varies in a small range, and on an average, it is 16.9 MJ / Kg (Marquard & Bahls, 2018) . In conifers it is 2% higher than in hardwoods. This difference is mainly due to the higher content of lignin, and partly also to the higher content of resin, waxes, and oils of conifers (AVEBIOM, 2008).

In this research, it is assumed that all the wood will be treated and processed as woodchips. There are other options like wood pellets that have less moisture content and more calorific value but need longer processes, more time, and more investment (AVEBIOM, 2008). Woodchips have a considerable moisture content (around 25%) which makes their net calorific value lower comparing with the gross calorific value, and it is of 15.3 MJ/kg or 4.25 kWh/kg on average (Marquard & Bahls, 2018). The net calorific value will be used in the calculations.

As explained in the methodology, this research understands that the most efficient, simple, and accessible process or technology to convert the wood in energy is via direct combustion of wood for heating and industrial purposes (Dornburg & Faaij, 2001). This combustion is done in woodchip boilers that use the combustion energy of the wood to heat water.

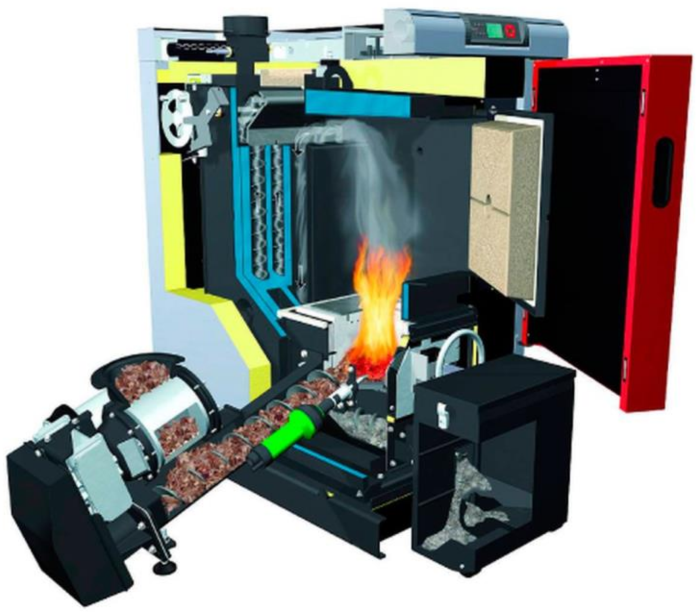


Figure 9. A wood chip boiler producing energy (Fröling GmbH, 2018).

The energy efficiency of wood chip boilers like the one above has achieved excellent results in the last years. The best boilers in the market have an efficiency of around 90% (Fröling, 2012). This efficiency is calculated in optimal situations that in real cases can be lower.

Other combustion processes have less energy efficiency and the processes that are directed to produce electricity from wood are not adequate in the Spanish system, as in other European nations, due to the complicated bureaucracy and difficulties to enter the grid, at least being an independent individual. In Spain, power utilities still control a monopoly on electricity production and distribution. In these circumstances, in the absence of a legal framework, independent power producers may not be able to invest in renewable energy facilities and sell power to the utility or to third parties (Beck & Martinot, 2004). If the situation changes, the option to generate electricity could be interesting in some cases.

Now that all the parameters to calculate the energy potential that Basque forests have been known (wood tonnes, net calorific value of wood and energy efficiency of the process) the calculation will be done. For the calculation, the formula in the research methodology part will be used (*Formula 2*).

The result of the calculation shows that the Basque forests have the potential to produce 53,700 TJ, respecting native forests. It would be the equivalent of the 20.6% of the total Basque energy demand of 2017.

CHAPTER 5 CONCLUSION

As seen through this research, Basque forests have the potential to generate 3,899,797 tonnes of wood per year, while respecting native species. Using the most efficient technologies, it could be converted into 53,700TJ per year. It would be 20.6% of the total Basque energy demand of 2017. This is a considerable percentage that should be considered by public institutions and policymakers to promote the use of the forests as an energy source, also the private sector.

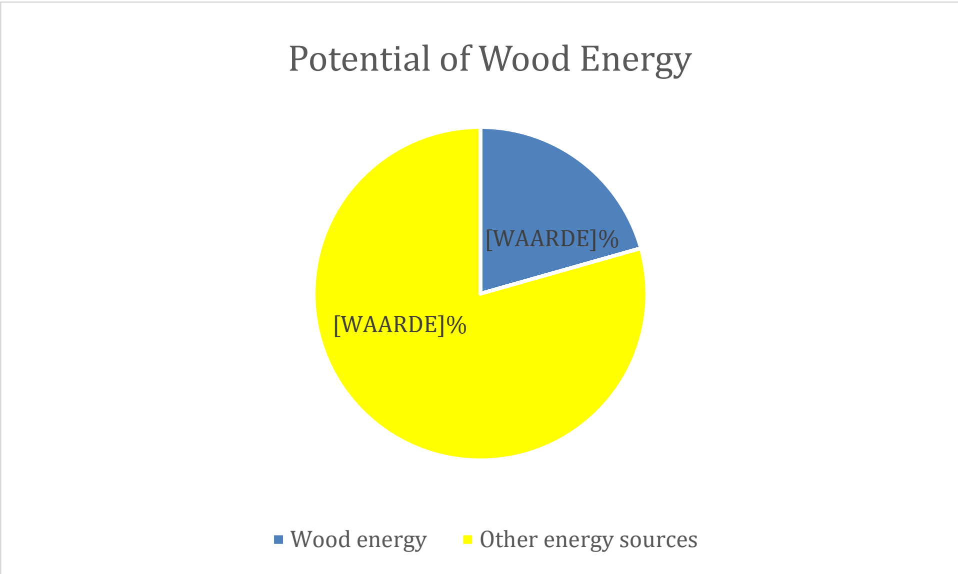


Figure 10. The potential of wood energy in the Basque total energy demand

The potential is the maximum energy that Basque forests can produce, estimating that all the factors of the calculation are in an optimal condition as the energy efficiency processes, wood production of different forests, and considering that all the forests are used for biomass production. It is important to note that all these optimal conditions are not always going to be accomplished due to different reasons (diseases, less efficient technologies, other forest uses) therefore, the real potential will be lower. It should also be considered that forests that are completely protected, where the use for wood production is not possible, have not been removed from the potential calculation. They have not been removed because it has been not possible to find detailed information on these forests and the species located within. Completely protected forests are a small number, but it would affect lowering the potential. The research calculates that the potential could have an error percentage of the 10%.

In conclusion, the potential that Basque forests have to be an energy source is high compared to other regions or countries in Europe. The potential that Basque forests have to produce energy is around 10 times higher than the actual use. That means that the forests could be used more for energy generation purposes.

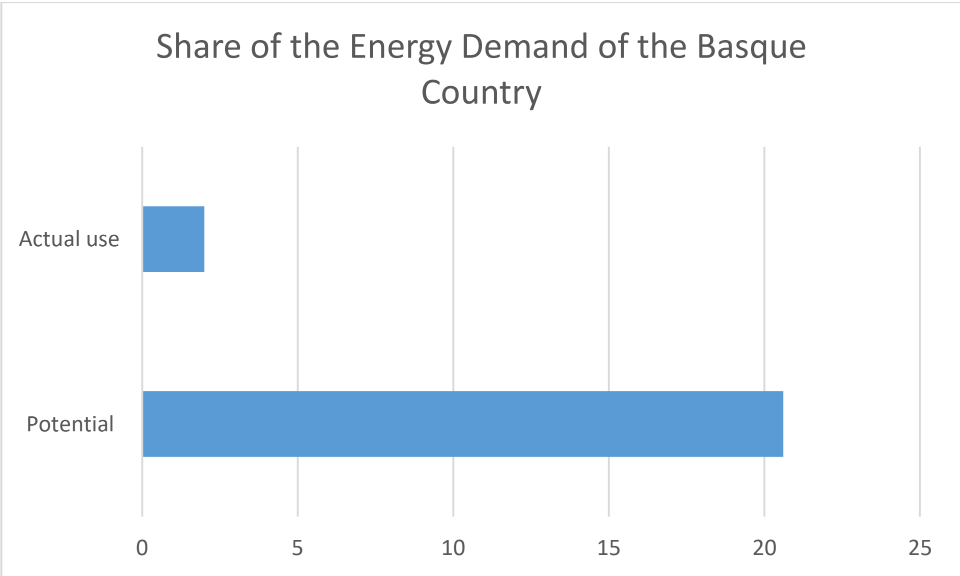


Figure 11. Actual use and potential of wood energy

It will always be very important to find a balance between the forests that are used for energy generation and the forests that produce wood for other purposes that are important for the local people and economy.

Higher use of the forests for energy production would increase the use of renewable energies in the region, and it would also help achieve the European targets for 2020, 2030, and 2050. It will also decrease the emission of tonnes of CO_2 in the atmosphere, contributing to the global warming process.

CHAPTER 6 RECOMMENDATIONS

The recommendations are a fundamental part of the research that aims to improve the understanding and the use of the concepts analyzed in the research. Most of the recommendations direct towards the understanding of the potential and how this research and its conclusions can apply in the real world.

This research calculated the maximum potential that Basque forests have to be an energy source while respecting native species. The research does not suggest that in the future all this potential should be used. The maximum potential has been calculated to show to the local authorities, private companies, and individuals that this bioenergy source has great potential in the region, and that it is an alternative to develop a Basque Country that is more renewable and energetically less dependent. The research recommends especially for public authorities to develop programs and plans to develop the use of this energy source. It is also suggested to find a balance between the use of the forests to produce wood for energy generation purposes, and other wood-based industries, and the protection of the environment and environmental services.

The research recommends first to start using wood from forests that do not have any economic use. This would generate new economic activities and would not affect the forests that are already being used for other activities. Forests that normally do not have any economic activity are native species. They are more linked with the protection of the environment and the supply of environmental services. The research recommends that these forests could be used extensively, producing low quantities of wood but without affecting the environmental services that they provide.

The next recommendation is dedicated to the energy efficiency of the processes. The supply chain of the wood is long, starting from the collection of wood from the forests until the wood is burned and converted into energy. This process has to be done locally, in an area not bigger than 40 km so not to use other energy sources in excess that would decrease the net energy generation. It is always recommended to use wood in combustion processes with the highest energy efficiency as possible, for that the newest technologies should be used. Wood is most efficiently used in wood boilers that produce heat for heating and industrial processes.

The last recommendation is directed towards institutions and individuals that would like to study more deeply about this topic. They should consider that this research is limited and has been done by one person and sometimes the data that was needed was not available. This study field could be developed in the future:

1. Get more information, if it is possible from the government database, to make the calculation more exact.
2. The research needs more specific data about completely protected forests and the species that are on them and in what condition.
3. There are different forest uses that have not been considered in the research, only extensive and intensive forest uses. Applying other uses to the potential could be more exact.
4. The methodology that is used in this research could be used in other regions, making some changes if needed.

REFERENCES

AgriInfo.in. (2015). Forestry - Definition and Types of Forestry. Retrieved June 15, 2018, from http://agriinfo.in/default.aspx?page=topic&superid=2&topicid=1605

Altuna, G. (2012). Biomasa. Retrieved from https://www.ehu.eus/documents/1294053/3185002/Gorka Altuna

ARBOLAPP. (n.d.). Quercus pyrenaica. Retrieved May 19, 2018, from http://www.arbolapp.es/en/species/info/quercus-pyrenaica/

Arrasateko Udala. (2015). Haritza aukeratu dute arrasatearrek. Retrieved from https://www.arrasate.eus/eu/albisteak/arrasatearrek-haritza-aukeratu-dute-arbolapetan-landatzeko

Atalaya, A. C. (1991). La Madera Como Combustible. Retrieved June 15, 2018, from http://infomadera.net/uploads/articulos/archivo_724_16609.pdf

Aula Silvicultura. (2008, October 20). Clases Naturales de Edad. Retrieved June 15, 2018, from https://silvicultor.blogspot.com/2008/10/clases-naturales-de-edad.html

Aula Silvicultura. (2010, October 3). Diámetro Normal o Diámetro a la altura del pecho. Retrieved from https://silvicultor.blogspot.com/2010/10/diametro-normal-o-diametro-la-altura.html

AVEBIOM. (2008). Manual de Combustibles de Madera. Retrieved from http://www.biomasstradecentre2.eu/scripts/download.php?file=/data/pdf_vsebine/Handbook/Handbook_E.pdf

AVEBIOM. (2012, February 8). Empleo: El argumento más contundente de la bioenergía. Retrieved from http://www.avebiom.org/es/noticias/News/show/empleo-el-argumento-mas-contundente-de-la-bioenergia-440

Azterlanak eta Planifikazioa Atala. (2017). *2016 Euskadi Energia Energia datuak Datos energéticos.* Retrieved March 12, 2018, from http://www.eve.eus/CMSPages/GetFile.aspx?guid=24632eca-2523-4fdc-a038-6853a797701a

Baffetta, F., Corona, P., & Fattorini, L. (2011, July 01). Assessing the attributes of scattered trees outside the forest by a multi-phase sampling strategy | Forestry: An International Journal of Forest Research | Oxford Academic. Retrieved June 1, 2018, from https://academic.oup.com/forestry/article/84/3/315/678207

Barea, J. (2017, December 21). Una alternativa a la incineradora de Zubieta. Retrieved from https://es.greenpeace.org/es/noticias/la-incineradora-de-zubieta-tiene-alternativa-un-nuevo-plan-de-residuos/

BaskEgur. (2016). ACTIVIDAD FORESTAL E INDUSTRIA DE TRANSFORMACIÓN DE LA MADERA. EVOLUCIÓN RECIENTE Y PERSPECTIVAS EN EUSKADI. *LIBRO BLANCO DEL SECTOR DE LA MADERA, 1*. Retrieved from file:///C:/Users/studiezaal/AppData/Local/Temp/Temp1_Libro-blanco-del-sector-de-la-madera.zip/Libro blanco. BASKEGUR.pdf.

BaskEgur. (2015). Sector-forestal-madera-vasco. Retrieved from http://baskegur.eus/el-sector-forestal-madera-de-euskadi-en-cifras/

BBC. (2018). GCSE Biology (Single Science) - Food chains - Revision 5. Retrieved from https://www.bbc.com/education/guides/z2m39j6/revision/5

Beattie, A. (2018, March 15). Sustainability. Retrieved from https://www.investopedia.com/terms/s/sustainability.asp

Beck, F., & Martinot, E. (2004). Renewable Energy Policies and Barriers. *Encyclopedia of Energy,* 365-383. doi:10.1016/b0-12-176480-x/00488-5

Benson, C. A. (1988). A Need for Extensive Forest Management. *The Forestry Chronicle, 64*(5), 421-430. doi:10.5558/tfc64421-5

Benson, C. A. (n.d.). The Potential For Integrated Resource Management With Intensive or Extensive Forest Management: Reconciling Vision With Reality - The Extensive Management ~Argumen. Retrieved June 1, 2018, from http://pubs.cif-ifc.org/doi/pdf/10.5558/tfc66457-5

Bioenergianeuvoja.fi. (2018). Wood Chips. Retrieved May 19, 2018, from http://www.bioenergyadvice.com/bio-fuels/wood-chips/

Bizkaia.Eus. (n.d.). Foru Aldundia - Diputación Foral. Retrieved May 19, 2018, from http://www.bizkaia.eus/home2/Temas/DetalleTema.asp?Tem_Codigo=8073&idioma=CA&dpto_biz=9&codpath_biz=9

BOE. (2014, April 15). Decreto Legislativo 1/2014, de 15 de abril, por el que se aprueba el texto refundido de la Ley de Conservación de la Naturaleza del País Vasco. Retrieved June 15, 2018, from https://www.boe.es/buscar/pdf/2014/BOE-A-2014-5595-consolidado.pdf

Boyle, J., Tappeiner, J., Waring, R., & Smith, C. T. (2016). Sustainable Forestry: Ecology and Silviculture for Resilient Forests. *Reference Module in Earth Systems and Environmental Sciences.* doi:10.1016/b978-0-12-409548-9.09761-x

CABI. (2018). Pinus radiata (radiata pine). Retrieved May 19, 2018, from https://www.cabi.org/isc/datasheet/41699

Castilla, F. (n.d.). Quercus pyrenaica. Retrieved from http://www.arbolapp.es/en/species/info/quercus-pyrenaica/

Ciolkosc, D. (2017). What is Renewable Energy? Retrieved May 31, 2018, from https://extension.psu.edu/what-is-renewable-energy

Chaparro, L. (2018). El eucalipto, entre el amor y el odio. Retrieved from https://www.oei.es/historico/divulgacioncientifica/reportajes164.htm

Costanzo, B. E. (2016, July 1). Forests through the Ages: The Importance of Young Forests. Retrieved June 15, 2018, from https://www.nrcs.usda.gov/wps/portal/nrcs/blogdetail/nrcsblog/home/?cid=NRCSEPRD1179414

Directive 2009/28/EC Of The European Parliament And Of The Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. (2009). Official Journal of the European Union, 011, 16-62. Retrieved from http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009L0028

Dornburg, V., & Faaij, A. P. (2001). Efficiency and economy of wood-fired biomass energy systems in relation to scale regarding heat and power generation using combustion and gasification technologies. *Biomass and Bioenergy*, *21*(2), 91-108. doi:10.1016/s0961-9534(01)00030-7

Ec.europa.eu. (2017). Natura 2000. Retrieved from http://ec.europa.eu/environment/nature/natura2000/index_en.htm

Edwards, P. J., & Abivardi, C. (1998). The value of biodiversity: Where ecology and economy blend. *Biological Conservation*, *83*(3), 239-246. doi:10.1016/s0006-3207(97)00141-9

Energias Renovables. (2016, January 07). Panorama - La dependencia energética de Euskadi es superior a la de todos los países de la UE menos Luxemburgo. Retrieved March 11, 2018, from https://www.energias-renovables.com/panorama/la-dependencia-energetica-de-euskadi-es-superior-20160107

Ente Vasco De La Energía. (2017). *Informe Anual 2016*. Retrieved from http://www.eve.eus/CMSPages/GetFile.aspx?guid=6f3fd739-3754-48a9-a4c3-894e12d391a1

Ente Vasco de la Energía. (2017). *Programa de Ayudas a Inversiones en Instalaciones de Aprovechamiento Energético de la Biomasa*(Publication No. 3216). Bilbao, BIZ. Ente Vasco de la Energía. (n.d.). EVE - Energy Policy Publications. Retrieved from http://www.eve.eus/Publicaciones/Planes-Energeticos.aspx?lang=en-GB

Ericsson, K., & Werner, S. (2016, September 01). The introduction and expansion of biomass use in Swedish district heating systems. Retrieved from https://www.sciencedirect.com/science/article/pii/S0961953416302793

Eupedia. (n.d.). Basque Country Travel Guide. Retrieved May 14, 2018, from https://www.eupedia.com/spain/basque_country.shtml

Europa.eu. (2018, May 24). Energía. Retrieved from https://europa.eu/european-union/topics/energy_es

European Commission. (2010). Communication from the Commission to the European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions Energy 2020 A strategy for competitive, sustainable and secure energy (Rep. No. 52010DC0639). Brussels, BE.

European Commission. (2018, March 09). Biomass. Retrieved March 12, 2018, from https://ec.europa.eu/energy/en/topics/renewable-energy/biomass

European Commission. (2013). *COMMUNICATION FROM THE COMMISSION A New EU Forest Strategy: For Forests and the Forest-Based Sector*(Rep. No. 52013DC0659). Brussels, BE. Retrieved from:

www.europarl.europa.eu/RegData/etudes/BRIE/.../EPRS_BRI(2015)568329_EN.pdf

European Commission. (2010).- *Report from the Commission to the Council and the European Parliament on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling SEC(2010) 65 final SEC(2010) 66 final*(Rep. No. 52010DC0011). Brussels, BE.

European Commission. (2014). *State of play on the sustainability of solid and gaseous biomass used for electricity, heating and cooling in the EU*(Working paper). Brussels, BE

Eurostat. (2018, February 26). Wood as a Source of Energy. Retrieved March 12, 2018, from: http://ec.europa.eu/eurostat/statistics-explained/index.php/Wood as a source of energy

Eurostat. (2018, June 7). Renewable energy statistics. Retrieved from http://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable_energy_statistics

Euskadi.eus. (n.d.). Euskal Herriko Agintaritzaren Aldizkaria. Retrieved June 1, 2018, from https://www.euskadi.eus/y22-bopv/eu/bopv2/datos/1994/07/9402695e.shtml

Euskadi.eus. (n.d.). Eusko Jaurlaritzaren informazioa, tramiteak eta zerbitzuak. Retrieved May 19, 2018, from http://www.euskadi.eus/hasiera/

Euskadi.eus. (2004). Mapa Forestal de la CAPV. Retrieved from http://www.nasdap.ejgv.euskadi.eus/contenidos/informacion/if_mapa_metodologia/es_dapa/adjuntos/2.3 y 4.pdf

Euskadi.eus. (2006, March 22). Flora vascular amenazada en la CAPV. Retrieved June 1, 2018, from http://www.euskadi.eus/web01-a2ingdib/es/contenidos/libro/flora_amenazada/es_15333/indice.html

Eusko Ikaskuntza. (2001). Bosque y territorio en el País Vasco. Retrieved May 17, 2018, from http://www.euskonews.com/0108zbk/gaia10803es.html

Eusko Jaurlaritza. (2011). *EUSKADIKO ENERGIA ESTRATEGIA 2030*(Publication).

Eusko Jaurlaritza. (2013). *LEY 2/2013, de 10 de octubre, de modificación de la Ley 16/1994, de 30 de junio, de Conservación de la Naturaleza del País Vasco.*(Spain, Basque Government, Conservación de la Naturaleza del País Vasco).

Eusko Jaurlaritza. (2014, February 05). Biodiversidad. Retrieved from http://www.euskadi.eus/informacion/biodiversidad/web01-a2ingdib/es/

Eusko Jaurlaritza. (2015, September 02). Espacios Naturales Protegidos (ENP_ES). Retrieved from http://www.geo.euskadi.eus/geograficos/espacios-naturales-protegidos/s69-geodir/es/Energía y Sociedad. (2016, December 11). REGULACIÓN ESPAÑOLA DE LAS ENERGÍAS RENOVABLES. Retrieved from http://www.energiaysociedad.es/manenergia/3-5-regulacion-espanola-de-las-energias-renovables/

Eusko Jaularitza. (2018). A map of the distribution of species in the Basque Country. Retrieved from http://www.geo.euskadi.eus/s69-15375/eu/

Eusko Jaularitza. (2018). Distribution of conifers and leafy trees. Retrieved from http://www.geo.euskadi.eus/s69-15375/eu/

Eustat. (2017). Eustat - Euskal Estatistika Erakundea - Instituto Vasco de Estadística. Retrieved May 16, 2018, from http://en.eustat.eus/indice.html

EVE. (2014). *Aprovechamiento de la biomasa en instalaciones deportivas, para usos térmicos. Convenio HAZI-EVE*(Rep.). Bilbao, BIZ: BFA.

Fao.org. (n.d.). An Argument for Intensive Forest Management. Retrieved June 1, 2018, from http://www.fao.org/docrep/ARTICLE/WFC/XII/0750-B1.HTM

Fao.org. (n.d.). 3. IDENTIFYING INTERESTED GROUPS THEIR VALUE PERSPECTIVES. Retrieved June 28, 2018, from http://www.fao.org/docrep/008/v7395e/v7395e06.htm

Forestry Commission England. (2017, November 17). Turning wood into woodfuel. Retrieved June 15, 2018, from https://www.forestry.gov.uk/forestry/infd-9qqln7#processing

Fröling. (2012). *Wood Chip and Pellet Boilers* [Brochure]. Grieskirchen, AT: Author.

Fröling GmbH. (2018). A wood chip boiler producing energy. Retrieved from https://www.froeling.com/nl/produkte/hackgut/tx.html

Ganoraz, A. G. (2015, January 28). Arrasatearrek haritza aukeratu dute Arbolapetan landatzeko. Retrieved May 19, 2018, from https://www.arrasate.eus/eu/albisteak/arrasatearrek-haritza-aukeratu-dute-arbolapetan-landatzeko

GeoEuskadi. (2018). Conifers distribution in the Basque Country. Retrieved from http://www.geo.euskadi.eus/s69-15375/eu/

GeoEuskadi. (2018). Distribution of quercus species in the Basque Country. Retrieved from http://www.geo.euskadi.eus/s69-15375/eu/

GeoEuskadi. (2018). Distribution of quercus species in the Basque Country. Retrieved from http://www.geo.euskadi.eus/s69-15375/eu/

GeoEuskadi. (2018). Protected nature areas in the Basque Country. Retrieved from http://www.geo.euskadi.eus/s69-15375/eu

Groome, H. (1987). SITUACIÓN ACTUAL Y PERSPECTIVAS FUTURAS DEL SECTOR FORESTAL DE LA COMUNIDAD AUTÓNOMA VASCA. Lurralde, 10, 185-204./

Günther, B., Gebauer, K., Barkowski, R., Rosenthal, M., & Bues, C. (2012). Calorific value of selected wood species and wood products. *European Journal of Wood and Wood Products*, *70*(5), 755-757. doi:10.1007/s00107-012-0613-z

Halkka, A., & Lappalainen, I. (2001). *Insight into Europe's Forest Protection*(Publication No. 2-88085-248-X). Gland, CH: WWF-World Wide Fund For Nature.

HAYA. (2005). Fagus sylvatica. Retrieved May 19, 2018, from http://www.euskadi.eus/

HAYA. (2005). Eucalipto. Retrieved May 19, 2018, from http://www.euskadi.eus/contenidos/informacion/inv_for_aprox_general_2005/es_dapa/adjuntos/Eucalyptus sp.pdf

HAZI. (2018). Corporación del Gobierno Vasco para el desarrollo del medio rural y marino. | HAZI. Landa, Itsasertz eta Elikagaien Sustapenta. Desarrollo Rural, Litoral y Alimentario HAZI. Landa, Itsasertz eta Elikagaien Sustapenta. Desarrollo Rural, Litoral y Alimentario. Retrieved from http://www.hazi.eus/eu/

Hodge, I. D., & Adams, W. M. (2013). The future of public forests: An institutional blending approach to forest governance in England. Journal of Rural Studies, 31, 23-35. Retrieved from https://www.sciencedirect.com/science/article/pii/S0743016713000144.

IDAE. (2011). *Evaluación del Potencial de Energía de la Biomasa* (Rep.). Madrid, MAD

Mapio.net. (n.d.). Zarautz desde el Botánico de Iturraran. Retrieved May 19, 2018, from http://mapio.net/pic/p-25222916/

Mapio.net. (n.d.). Bosque mixto de frondosas junto al Jardin Botánico de Iturraran. Retreived from https://mapio.net/pic/p-25730155/

Marquard & Bahls. (2018). Net Calorific Value & Gross Calorific Value. Retrieved from https://www.marquard-bahls.com/en/news-info/glossary/detail/term/calorific-value.html

Mckendry, P. (2002). Energy production from biomass (part 2): Conversion technologies. *Bioresource Technology, 83*(1), 47-54. doi:10.1016/s0960-8524(01)00119-5

Mendilerroa, G. (2016, December 27). Sierra Sálvada. Retrieved May 15, 2018, from http://sierrasalvada.blogspot.nl/search/label/Quercus faginea subsp. faginea

Mendilerroa, G. (2017, November 8). Sierra Sálvada. Retrieved May 16, 2018, from http://sierrasalvada.blogspot.nl/search/label/Pinus sylvestris

Mendilerroa, G. (2018, February 16). Pinus nigra subsp. laricio. Retrieved May 19, 2018, from http://sierrasalvada.blogspot.nl/2018/02/pinus-nigra-subsp-laricio.html

Mikipons, (2018). Pago lepatuak, Otzarreta pagadia. Retrieved from https://eu.wikipedia.org/wiki/Lepatze#/media/File:Hayedo_Otzarreta_Gorbeia_1.jpg

Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente. (n.d.). Inventario Forestal Nacional. Retrieved March 13, 2018, from http://www.mapama.gob.es/es/desarrollo-rural/temas/politica-forestal/inventario-cartografia/inventario-forestal-nacional/

Montagu, K., Kearney, D., & Smith, R. (2003). The biology and silviculture of pruning planted eucalypts for clear wood production—a review. *Forest Ecology and Management, 179*(1-3), 1-13. doi:10.1016/s0378-1127(02)00579-0

Nadeau Fortin, M. A., Sirois, L., & St-Laurent, M. H. (2016, May 9). Canadian Journal of Forest Research. Retrieved June 1, 2018, from http://www.nrcresearchpress.com/doi/10.1139/cjfr-2016-0038#.WxCIoEiFPIV

Observatorio Indusrial de la Madera. (2010). ESTIMACIÓN DE LA BIOMASA FORESTAL POTENCIALMENTE APROVECHABLE EN LA PROVINCIA DE SEGOVIA. Retrieved June 15, 2018, from http://www.mincotur.gob.es/industria/observatorios/SectorMadera/Actividades/2010/Federación de Construcción, Madera y Afines de Comisiones Obreras/Documento_final_FECOMA.pdf

Ochoa Palcios, M. A. (2014, May 07). RESIDUOS FORESTALES. Retrieved May 31, 2018, from https://prezi.com/plrfeadz5wnt/residuos-forestales/

Olano, J. M. (1995). Vegetación. Retrieved from http://www.bizkaia.eus/home2/Temas/DetalleTema.asp?Tem_Codigo=8073&idioma=CA&dpto_biz=9&codpath_biz=9

Ormazabal, J. M. (2016, November 23). Política Energética Sostenible 2050, reto para el nuevo Gobierno vasco. Deia, Noticias de Bizkaia. Retrieved from http://www.deia.eus/2016/11/23/opinion/tribuna-abierta/politica-energetica-sostenible-2050-reto-para-el-nuevo-gobierno-vasco

Pagiola, S. (2004). *Selling forest environmental services: Market-based mechanisms for conservation and development*. London: Earthscan Publications.

Prado, J. A. (2010). Guide to implementation of phytosanitary standards in forestry. *FAO Forestry Paper*. Retrieved June 28, 2018, from http://www.fao.org/3/a-i2080e.pdf .

Perez de Ana, J. M. (2016). Quercus faginea subsp. faginea. Retrieved from http://sierrasalvada.blogspot.com/search/label/Quercus%20faginea%20subsp.%20faginea

Perez de Ana, J. M. (2017). Black Pines in Araba. Retrieved from http://sierrasalvada.blogspot.com/2018/02/pinus-nigra-subsp-laricio.html

Perez de Ana, J. M. (2017). Scots Pines in Araba. Retrieved from http://sierrasalvada.blogspot.com/search/label/Pinus%20sylvestris

Perez de Ana, J. M. (2018, March 12). Eucalyptus Nitens. Retrieved May 19, 2018, from http://macizodelgorbea.blogspot.nl/2018/03/eucalyptus-nitens.html

Perez de Ana, J. M. (2018, March 12). Macizo del Gorbeia. Retrieved May 19, 2018, from http://macizodelgorbea.blogspot.nl/2018/03/eucalyptus-nitens.html

Poudel, B. C., Sathre, R., Bergh, J., & Gustavsson, L. (2011, October 20). Potential effects of intensive forestry on biomass production and total carbon balance in north-central Sweden. Retrieved June 15, 2018, from https://www.sciencedirect.com/science/article/pii/S146290111100147X

PowerWorld Analysis. (2017, April 20). Biomass Energy Definition - What is Biomass Energy? Retrieved March 12, 2018, from http://www.powerworldanalysis.com/biomass-energy-definition/

Rainforest Alliance. (2016, July 28). What is Sustainable Forestry? Retrieved March 29, 2018, from https://www.rainforest-alliance.org/articles/what-is-sustainable-forestry

Ramos, J. H., Magaña, J. J., Flores, H. J., Cuevas, X. G., Reyes, T. S., López, C. F., & Ramos, A. H. (2018). GUÍA DE DENSIDAD PARA MANEJO DE BOSQUES NATURALES DE Pinus teocote Schlecht. et Cham. EN HIDALGO. *Revista Mexicana De Ciencias Forestales, 4*(19), 62-77. doi:10.29298/rmcf.v4i19.379

Redacción Interempresas. (2012, December 21). Los beneficios económicos de las energías renovables son muy superiores a sus costes. Retrieved from http://www.interempresas.net/Energia/Articulos/103861-Los-beneficios-economicos-de-las-energias-renovables-son-muy-superiores-a-sus-costes.html

Redactor. (2016). Provinces and capitals of the provinces of the Basque Country. Retrieved from http://www.gipuzkoagaur.com/2017/10/16/euskadi-en-aviso-amarillo-por-riesgo-de-incendios-y-fuertes-vientos/

Regos, A. (2016, June 09). Forest biomass extraction for energy uses: an opportunity to reduce the impact of large forest fires in Mediterranean ecosystems? Retrieved May 19, 2018, from https://adrianregosresearch.wordpress.com/2016/05/31/forest-biomass-extraction-for-bioenergy-an-opportunity-to-reinforce-the-convergence-of-forests-economy-and-green-energy/

Rehnus, M., Nazarek, A., Mamadzhanov, D., Venglovsky, B. I., & Sorg, J. (2013). High demand for firewood leads to overuse of walnut-fruit forests in Kyrgyzstan. *Journal of Forestry Research*, *24*(4), 797-800. doi:10.1007/s11676-013-0367-4

Sanchez, A. (2018, January 17). Conoce cuáles son las especies o maderas de coníferas e identifícalas. Retrieved from https://www.maderea.es/conoce-cuales-son-las-coniferas-e-identificalas/

Segura, F. (2015, February 17). Los ahorros en un pinar. Retrieved May 19, 2018, from http://www.diariovasco.com/gipuzkoa/201502/17/ahorros-pinar-201502170627.html

Segura F. (2015). Plantación de pinos en el monte Kurtzetxiki, en Arrasate. Retrieved from https://www.diariovasco.com/gipuzkoa/201502/17/ahorros-pinar-201502170627.html

The Morton Arboretum. (n.d.). European beech. Retrieved May 12, 2018, from http://www.mortonarb.org/trees-plants/tree-plant-descriptions/european-beech

UNESCO. (n.d.). Biosphere Reserves | United Nations Educational, Scientific and Cultural Organization. Retrieved June 1, 2018, from http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/biosphere-reserves/

Vasco, E. J. (n.d.). Nekazaritza, Arrantza eta Elikagai industria - Eusko Jaurlaritza. Retrieved May 19, 2018, from http://www.euskadi.eus/eusko-jaurlaritza/nekazaritza-arrantza-elikagai-industria/hasiera/

Vasco, E. J. (n.d.). GeoEuskadi, Euskadiko Datu Espazialen Egitura (DEA). Retrieved May 14, 2018, from http://www.geo.euskadi.eus/s69-15375/eu/Valorización de la Biomasa en el País Vasco. (2001). *Report from the Ente Vasco de la Energía.* Retreived March 13, 2018, from: http://www.eve.eus/CMSPages/GetFile.aspx?guid=8512077b-883d-4239-8ab9-39e2aeba2bca

Verkerk, P. J., Levers, C., Kuemmerle, T., Lindner, M., Valbuena, R., Verburg, P. H., & Zudin, S. (2015). Mapping wood production in European forests. *Forest Ecology and Management, 357*, 228-238. doi:10.1016/j.foreco.2015.08.007

Wa.gov.au. (2016, April 15). Radiata pine. Retrieved May 19, 2018, from http://www.fpc.wa.gov.au/node/906

Zabalgarbi. (2012, April 29). La incineradora de Bilbao genera el 40% de la electricidad que consumen los hogares vizcainos. Retrieved from http://www.zabalgarbi.com/eu/la-incineradora-de-bilbao-genera-el-40-de-la-electricidad-que-consumen-los-hogares-vizcainos-2/

Zhang, S., Gilless, J. K., & Stewart, W. (2014). Modeling price-driven interactions between wood bioenergy and global wood product markets. Biomass and Bioenergy, 60, 68-78. doi:10.1016/j.biombioe.2013.10.027

APPENDIX

The appendix is used to explain the actual situation of Basque forests more deeply, explaining the most important forest species and their characteristics. The forests are divided on two groups due to their characteristics: conifers and eucalypts species, and hardwood species.

1 Conifers and Eucalypts Species

The conifers are a family of tree species related with pines. They have characteristic leaves, and the trees do not lose them entirely in any season of the year. They are known for having a high productivity of wood in a relatively short period of time.

1.1 Radiata Pine

Located on the Cantabrian slope, Pinus Radiata or Radiata Pine is the species that occupy the most significant area (123,921 ha, accounting for 31.2% of the total wooded forest area) and about 85-90% greater forest productivity in the Basque Country (Eusko Ikaskuntza, 2001). Originally from lower California (known as Monterrey pine), it is usually planted on land of fewer than 600 meters, with a deep, non-waterlogged soil (wa.gov.au, 2016). 85% of its surface belongs to private owners (Inventario forestal CAV). It is an invasive species that changed the ecosystems and biodiversity of the region, generating several negative impacts as soil erosion and impoverishment (CABI, 2018).

Figure 12. Pinus radiata monoculture in a town of Gipuzkoa (Segura, 2015).

1.2 Scots Pine

After Pinus radiata, Scots Pine (pinus Silvester) is the largest conifer of extension in the Basque Country (17,511 ha, about 14,000 of them in the form of natural masses) (Inventario forestal CAV). However, its distribution is radically different from that of the radiata pine, since it is a species of the Mediterranean slope. Most of them are located in the southern province of Araba. 80% of its extension is located in public forests. It is the only native conifer of the Basque Country; it arrived without any human activity to the region. They are not intensively used for wood production as Pinus Radiata due to its lower productivity, but they have high paisagistic value (EnteVasco).

Figure 13. Scots Pines in Araba (Pérez de Ana, 2017).

1.3 Black Pine

Pinus nigra or Black Pine, covers an area of 13,885 hectares, with predominant distribution in Gipuzkoa (51%). It usually appears in altitudes between 600 and 1,200 meters. It is more productive than Pinus Radiata in these altitudes, but its wood is less valuable. This is why it is not very extended.

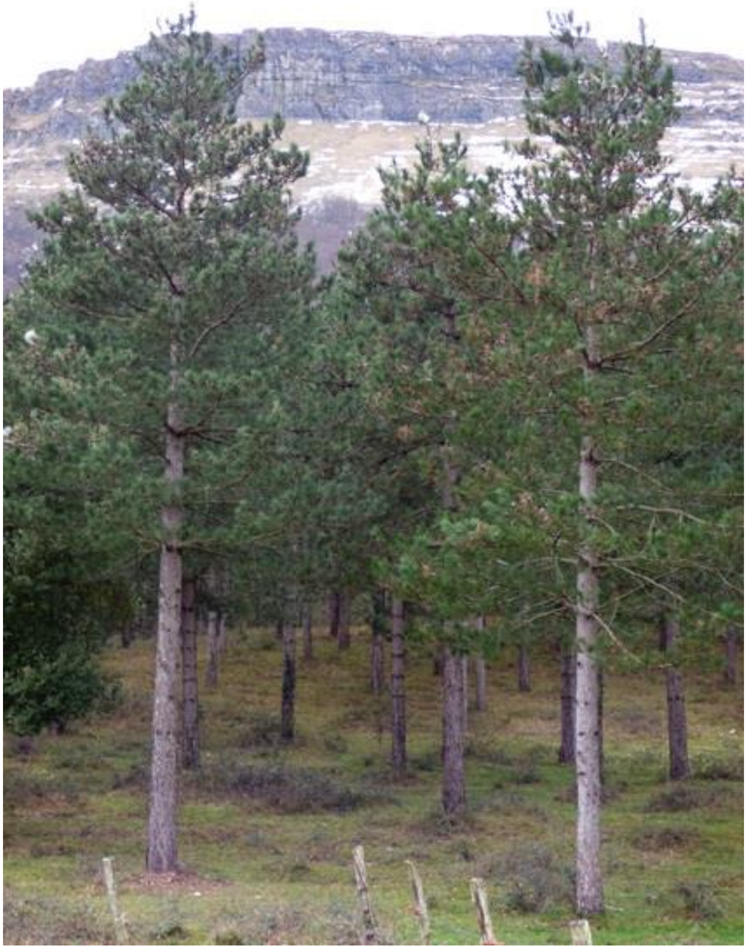


Figure 14. Black pines in Araba (Pérez de Ana, 2017).

In the map below, it is shown how the conifer species are distributed in the Basque Country:

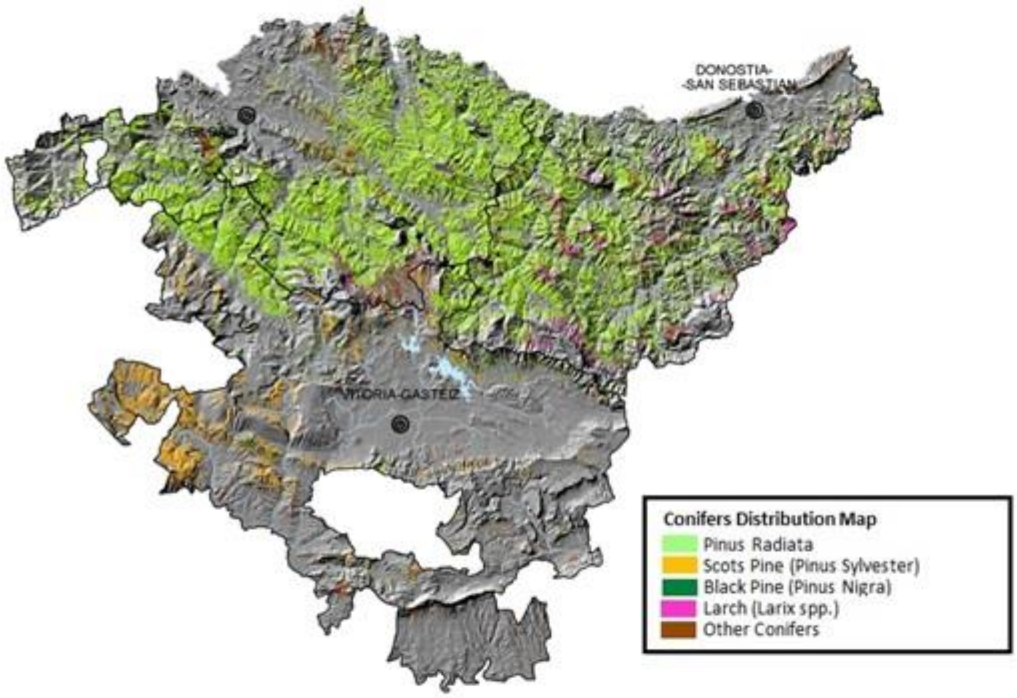


Figure 15. Conifers distribution in the Basque Country (GeoEuskadi, 2018).

1.4 Eucalypts

Eucalypts, mainly *Eucalyptus globulus* in the coastal zone of Bizkaia and *Eucalyptus nitens* in the interior of Bizkaia, below 500 meters are increasing in area year after year. Currently, they already reached an area of 18,194 hectares in 2017 and it is estimated that their annual increase will be around 500 hectares per year (HAYA, 2005). The productivity of wood of this species is very high and it is being used to replace *pinus radiata* plantations that are suffering from different illneses lately and because they adapt really well to poor soils. They are very popular inside the wood industry due to its productivity but they also have some negative impacts in the environment that have to be taken into account. For example, they completely change the biodiversity of the region, they have huge water needs, and are very vulnerable to wildfires.

Figure 16. An eucalyptus plantation in Bizkaia (Pérez de Ana, 2018).

2 Hardwood Trees

Leafy Trees are trees that are mostly autochthonous in the Basque Country, and one of their most notorious characteristics is that they lose their leaves in winter. They are normally less productive than Conifers in regards to wood production.

2.1 The European Beech

The Beech (*Fagus sylvatica*) is the leafy one that, with 54,619 ha and 14% of the wooded forested area, occupies the greater area in the autonomous community, centered in Araba (60%) and Gipuzkoa (32%). It occupies mountainous terrain, preferably of Umbria and with high degrees of atmospheric humidity (The Morton Arboretum). Three-quarters of the Beech surface are found in public forests, forming large continuous extensions on the northern slopes of the mountain ranges (HAYA, 2005). The Beech has been a traditional source of firewood and charcoal for the Basque people for centuries. Small pieces of wood were cut from the tree or taken from the ground for its use without hurting the tree severely, like this it would continue accumulating biomass (wood) for other needs in the future. This sustainable management of the resources was positive for the inhabitants and the trees, eliminating the diseases and problems in the tree's growth. Nowadays, this use of the Beech is disappearing due to the location of the Beeches and the change to other species like Pines. Lately, Beech forests are accumulating wood that could be used for its energetic use.

Figure 17. Beech forests in Gipuzkoa (Mikipons, 2018).

2.2 Oaks

The oaks, pedunculated (*Quercus robur*) and apricot (*Quercus petraea*), once occupied great areas of the Basque Country. Today they are relegated to dispersed areas, due to the pressure received by their habitat, the value of their wood, and the competition of other species. The common or pedunculated oak is preferably located in valleys and bottoms of valleys, on deep and fertile soils, in lands that are currently dominated by meadows and crops. Nowadays, most of these habitats are destroyed to build cities or for their agricultural use. Pure oak groves are scarce (16,598 ha), predominantly small diameter masses and coming from shoots of strain (Inventario forestal CAV).

*Figure 18.*A common oak in a town from Gipuzkoa (Arrasateko Udala, 2015).

The Holm Oak (*Quercus ilex*) is the most representative forest species of the Mediterranean mountain and occupies 26,364 ha. The Holm Oaks are mainly located in Araba (73% of its extension). There are masses of significant areas in the Cantabrian slope as well, coinciding in both cases with the main limestone mountains.

Figure 19. Holm Oaks in Araba (Olano, 1995).

The Gall Oak (*Quercus faginea*), given its tendency to the Mediterranean climate and limestone substrates, is located mainly in Araba. Its area has been greatly diminished as a consequence of the introduction of pastures and crops, so it has been relegated today to scattered forests in the foothills of some mountains, occupying 26,665 ha in total.

Figure 20. Gall Oaks in Araba (Pérez de Ana, 2016).

Quercus pyrenaica or Pirinean Oak is also one of the species centered on Araba (95% of its extension), and its are is estimated at 13,110 ha. The great capacity of regrowth of their strains and the poverty of the soils where they settle have favored the conservation of this species.

Figure 21. Pirinean Oaks in Araba (Castilla).

In the map below, it is shown how the quercus species are distributed.

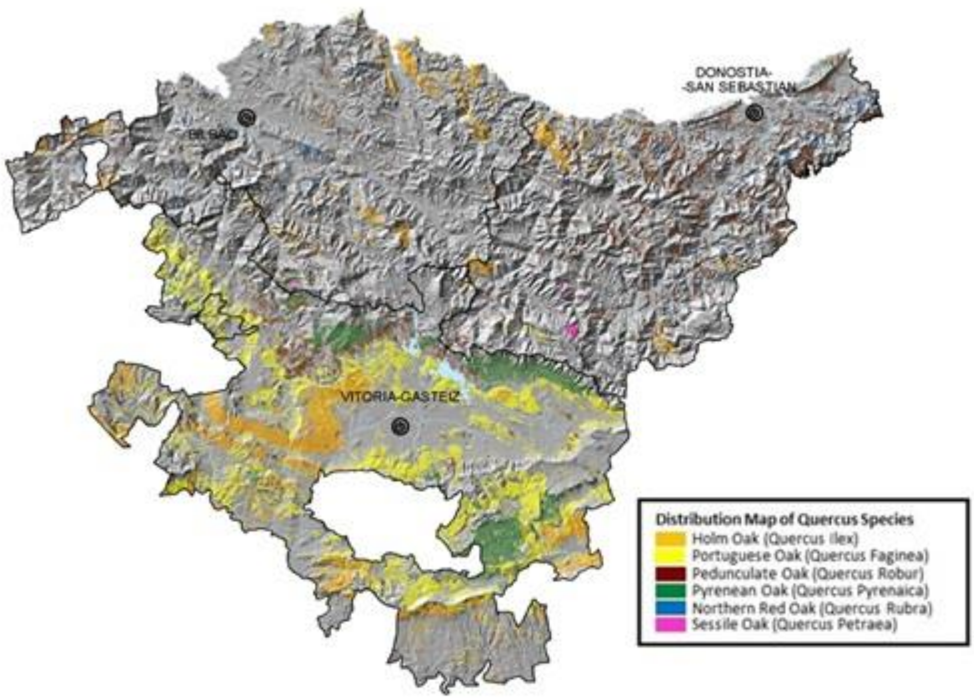


Figure 22. Distribution of quercus species in the Basque Country (GeoEuskadi, 2018).

2.3 Mixed Atlantic Forest

Mixed atlantic forests are heterogeneous mixtures of hardwoods dominated by feet from the stock that abound in the Cantabrian slope. In these forests, during the absence of disturbances, the longevity of common oak usually leads to its long-term dominance. They are a type of forest that expands every year as a result of the abandonment of pastures or cut pine forests; they occupy 35,414 hectares, 18,900 of them in Gipuzkoa (where they represent 15.3% of the total wooded area). They normally do not have any economic use.

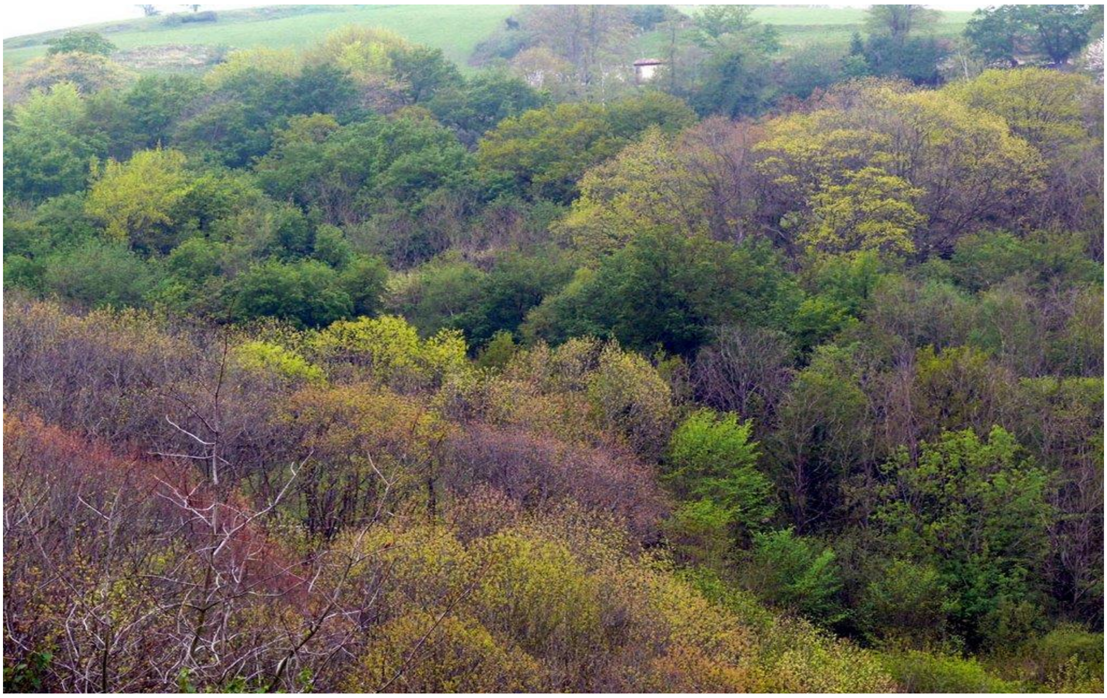


Figure 23. An example of a Mixed Atlantic forest in Gipuzkoa (Mapio.net).

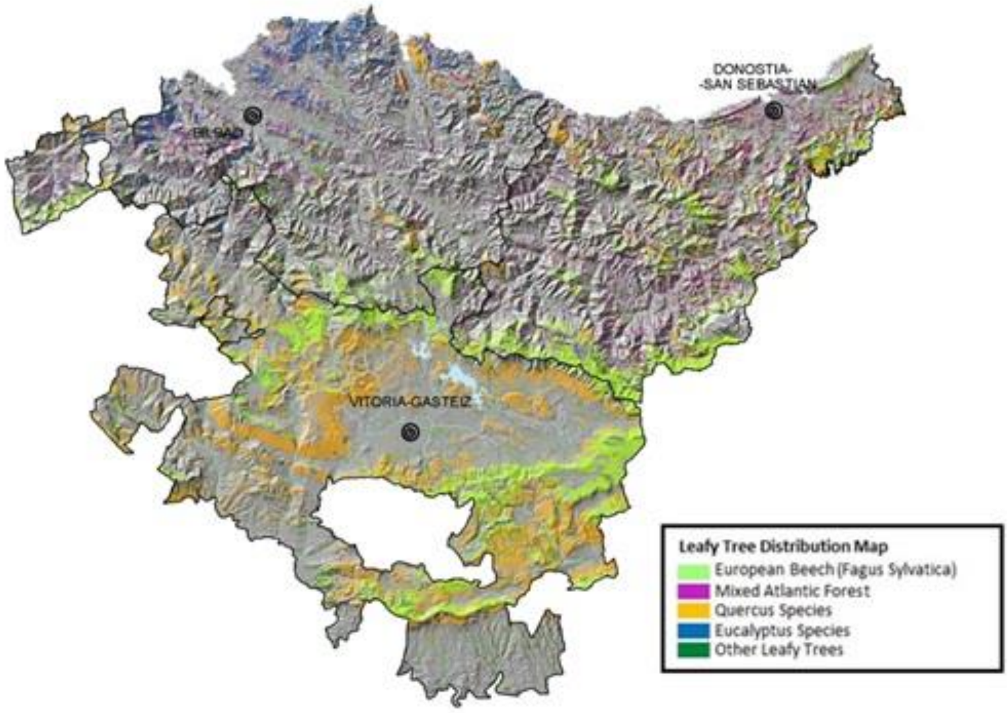


Figure 24. Distribution map of Leafy Trees (GeoEuskadi, 2018).