BIOPATH

Biomass and Solid Biofuels certification and traceability control System

Report outlining work performed by CERTH/ISFTA during Activity 4:

Solid Fuels Full Life Cycle Assessment

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Interreg IVc Program

Bio-En-Area project

BioPath Sub-project

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1. INTRODUCTION

1.1 Global energy – issues to be considered

As is well documented, the unprecedented development that the world has experienced since the 1950's, has been based upon our insatiable appetite for energy. Recent statistical data from IEA (2007) show that 81% of the total commercial energy consumed in the world was derived from fossil sources, while in the transport sector the figure was even higher, standing at 98%. Serious concerns about the future availability of those non-renewable fuels are increasingly prominent in public awareness and discourse. For a number of years the focus has mainly fallen upon crude oil, with clear divisions amongst researchers who predict a near future peak in oil production (e.g. Aleklett and Campbell, 2003; Almeida and Silva, 2009; Bentley, 2002; Campbell and Laherrere, 1998; Jakobsson et al., 2012) and those that see no availability problems in the foreseeable future (e.g. Jackson, 2006; Maugeri, 2004; Odell, 2010; Radetzki, 2010). Lately, peak gas (Laherrere, 2003; Simmons, 2007) and peak coal (Almeida and Silva, 2009) production have also been investigated.

The anxiety that surrounds the availability of fossil resources is compounded by issues relating to accessibility and affordability, a common theme in energy security discussions (Winzer, 2012). There is agreement that the continuity of supply is subject to a multitude of risks that can be broadly divided into three categories: technical risk sources, natural risk sources and human risk sources (Gnansounou, 2008; Rutherford et al., 2007). Technical risk sources include failure of infrastructure components such as transmission lines, power plants or transformers due to a failure of interdependent infrastructure such as communication networks. Natural risk sources are events such as intermissions in renewable energy supplies and natural disasters (Almeida and Silva, 2009). Although both of the aforementioned risk sources can have important implications for the continuity of energy supplies, any effects can be expected to be short term (Winzer, 2012). Human risk sources can have far wider implications, as they concern events such as, strategic withholding of supplies, terrorism and geopolitical risks (Kruyt et al., 2009). Thus, the debate about the future sustainability of global energy markets, centers on the emergence of new consumers such as China and India (Sahira and Qureshi, 2007; Zhang, 2011), the phenomenon of recourse nationalism (Stegen, 2011), the discrepancy in reserve holding between National Oil Companies (NOCs) and International Oil Companies (IOCs) (Winzer, 2012) and the political instability that characterizes many fossil fuel producer countries (Ross, 2001).

Arguably, the energy production drawbacks highlighted above pale into insignificance compared to the environmental problems emanating from the use of fossil fuels. Prominent amongst these are the results that anthropogenic greenhouse gas (GHGs) emissions have on the planet's climate. The 2007 Intergovernmental Panel on Climate Change scientific assessment stated with "very high confidence" that global warming is a serious problem that has anthropogenic influences, and that it must be addressed immediately (IPCC, 2007). The impacts of the increased GHG concentrations have been well documented and a growing body of scientific studies anticipate that nearly all world regions will be affected (e.g. Alcamo et al., 2007; Biesbroeka et al., 2010; Duttaa and Radnerb, 2009). The two principal sources of concern are rising sea-levels, which will mainly affect low-lying coastal areas such as Bangladesh and the Netherlands, and changes in the climate, which will result in tropical countries becoming more arid and less productive agriculturally, increased likelihood of natural disasters (hurricanes, fires and forest loss), and irreparable damages to the natural habitat of many living organisms (e.g. Beilin et al., 2012; Omann et al., 2009; WBGU, 2006).

The global strategy to reduce dependence on fossil resources is based on reducing energy consumption, by applying energy savings programs focused on energy demand reduction and energy efficiency in the transportation, industrial and domestic sectors, and by developing and promoting RES's.

1.2 Challenges to renewable energy development

The main challenges to Renewable Energy Systems (RES) development and competitive installation are to reduce their high cost (EC, 2007; Lund, 2009; Schreyer and Mez, 2008), improve the grid infrastructure (EC, 2007; Schreyer and Mez, 2008), increase financing for research and infrastructures, especially large-scale facilities , develop storage mechanisms, incentivise innovation by small and medium businesses (Jagoda et al., 2011; Schreyer and Mez, 2008), promote competitive fossil and renewable energy systems simultaneously (Kranzl et al., 2006), train more technicians and specialists (Jagoda et al., 2011; Schreyer and Mez, 2008), create proper market mechanisms to build a real internal market for green power (Jagoda et al., 2011; Lund, 2009), facilitate export, simplify administrative procedures and improve institutional and economic agreements (EC, 2007; Schreyer and Mez, 2008) through greater interaction between technology and politics that incentivise and improve access to RES on the power market (Defra, 2002; Kranzl, 2006). Social acceptance of the RES must also be improved (EC, 2007; Schreyer and Mez, 2008) and any local impact be reduced (Dincer and Rosen, 1998). Omer (2008) believes that renewable energies are environmentally-friendly when they are developed sensibly and appropriately, and have the complete participation of local communities. do Valle Costa et al. (2008) feel that regardless of the mechanism applied to promote RES, political support and interest and participation by local and regional stakeholders condition the success or failure of their promotion. It is therefore important to include any use of RES in urban and regional planning (Schreyer and Mez, 2008). The challenges highlighted in this section apply to all RES technologies. Challenges specific to bioenergy will be touched upon in following sections (please see 1.5).

1.3 EU specific energy challenges

The challenges to the position of the European Union (EU) emerge not only from the external factors highlighted in section 1.1, but also from a set of internal developments. These involve the process of dual integration, including the Union's enlargement towards central Europe, in combination with a continuous deepening of market integration. The process of enlargement brings new MS into the EU, with specific patterns of energy supply and demand, based on their former orientation towards the former Soviet. The ongoing integration of markets and policies in the EU influences the scope and the effectiveness of the instruments and approaches available to its MS and the Commission, to achieve their energy policy objectives (Correlje and van der Linde, 2006).

Furthermore, although the EU's 27 MS have ceded some national sovereignty to EU institutions in a variety of areas, including economic and trade policy, energy policy remains primarily the responsibility of the MS. Decisions regarding long-term oil or gas purchases, the development and improvement of energy-related infrastructure, and the use of particular fuels continue to be made at the national level by individual MS.

1.4 Energy policy in the EU

Arguably, the EU has been one of the most vocal advocates of the need to adopt and implement global schemes that will help reduce GHG emissions, and a driving force behind the conception of the Kyoto Protocol. Within the framework of engagements that arise from the Protocol, the EU has committed to the reduction of GHG emissions by 8% in the period 2008–2012. The relevant commitments of all EU Member States (MS) are presented in Table 1. It should be noted that a number of countries (namely, Sweden, Ireland, Spain, Greece and Portugal) were actually allowed to increase their GHG emissions from the base year.

Table 1: Greenhouse gas emission targets in EU under the Kyoto Protocol (2008-2012)

Country	GHG emission target (%)	Country	GHG emission target (%)
Germany	-21.0	Spain	+15.0
United Kingdom	-12.5	Poland	-6.0
Italy	-6.5	Romania	-8.0
Denmark	-21.0	Czech Republic	-8.0
Netherlands	-6.0	Bulgaria	-8.0
Belgium	-7.5	Hungary	-6.0
Austria	-13.0	Slovak Republic	-8.0
Luxemburg	-28.0	Lithuania	-8.0
Finland	0.0	Estonia	-8.0
France	0.0	Latvia	-8.0
Sweden	+4.0	Slovenia	-8.0
Ireland	+13.0	Cyprus	no target
Portugal	+27.0	Malta	no target
Greece	+25.0		

Source: adopted by EEA, 2010

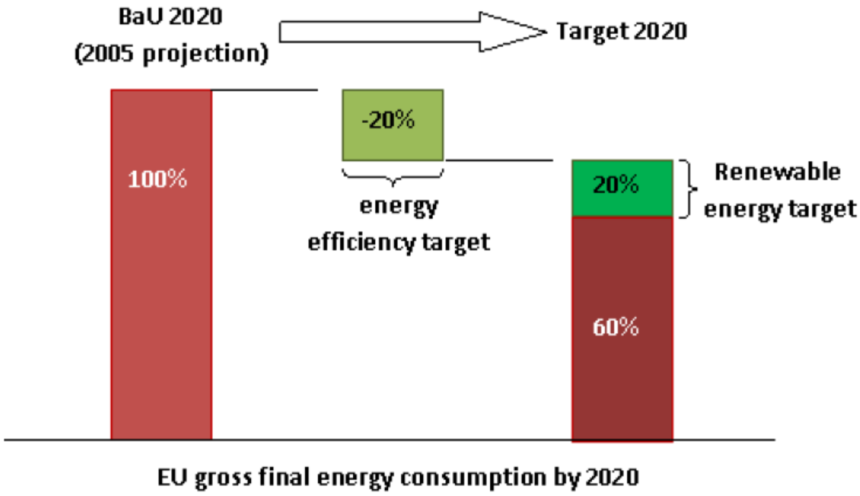

Figure 1: EU climate and energy targets and their interdependency

Source: Atanasiu, 2010

Undoubtedly, the EU Renewable Energy Directive (RED) on the promotion of the use of energy from renewable sources is a powerful measure at the heart of European energy and climate policy. The RED is part of the European Commission's Climate and Energy Package from 2008, which lays out a strategy for the EU-27 MS to reduce their collective greenhouse gas emissions by at least 20% and to increase the share of renewable energy to 20% of total consumption by 2020.

The Climate and Energy Package reiterated also the energy efficiency indicative target of reducing primary energy consumption by 20% compared with a business-as-usual (BaU) scenario by 2020. Indeed all these three targets are interconnected and influence each other: a reduction in energy consumption makes is easier to reach the renewable energy target and both contribute to lowering GHG emissions (Fig. 1).

The RED sets out binding targets aimed at the promotion of renewable energy. The overall target requires the delivery of an EU-wide 20% share of renewable energy in gross final energy consumption by 2020, with the level of effort differentiated across Member States as specified in Annex A of the Directive. A sub-target specifically promotes the use of energy from renewable sources within the transport sector, requiring 10% of all transport fuels to be delivered from renewable sources by 2020 in every Member State. When the RED was adopted, it was unclear precisely which technologies and approaches would MS choose in order to deliver these targets. Article 4 of the RED specifically requires Member States to produce and submit National Renewable Energy Action Plans (NREAPs) by 30 June 2010, outlining their national approaches and roadmaps in meeting the 2020 renewable targets. Consequently, the NREAPs are very important to understanding the anticipated consequences associated with meeting the EU RED targets.

Table 2 outlines the intermediate objectives for the transport sector set by each country6 in their respective action plans. Figures are shown as the RES percentage of final energy consumption in the transport sector. Only nine countries intended to comply with this objective on that date, with almost all other countries developing scenarios for 2020 in which their renewable energy participation is higher than or equal to the objective set by Directive 2009/28/EC. Bulgaria, Cyprus and Estonia, however, do not expect to reach that minimum by 2020. The country with the most ambitious objective for 2020 is Finland, which hopes to reach 20%. Ireland (16%), Sweden (13.8%), Spain (13.6%), Germany (13.2%) and Austria (11.4%) follow some distance behind (Cansino et al., 2012).

Table 2: Objectives for renewable energy participation as a percentage of final energy consumption in the transport sector (2005–2020)

Country	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Germany	3.9	7.3	7.5	7.6	7.0	7.0	7.0	7.1	9.3	9.4	9.7	13.2
Austria	2.3	6.8	6.9	7.0	7.2	7.4	7.7	8.1	8.5	9.2	10.1	11.4
Belgium	0.0	3.8	3.8	4.8	4.8	5.7	5.8	6.3	6.5	7.9	9.0	10.14
Bulgaria	1.12	1.3	2.0	2.6	3.1	3.8	4.4	4.9	5.8	6.4	7.0	7.8
Cyprus	0	2.2	2.4	2.5	2.8	2.9	3.1	3.5	3.8	4.2	4.6	4.9
Denmark	0.2	1.0	3.5	5.9	6.0	6.0	6.7	7.3	7.9	8.6	9.4	10.1
Slovakia	0.6	4.1	4.2	4.3	4.4	5.0	6.0	6.3	6.8	8.3	8.5	10.0
Slovenia	0.3	2.6	2.8	3.1	3.5	4.0	4.7	5.6	6.6	7.7	9.0	10.5
Estonia	0.0	0.0	0.0	0.6	1.2	1.3	1.3	1.6	1.8	2.1	2.4	2.7
Spain	1.1	6.0	6.1	6.5	6.5	8.2	9.3	10.4	11.1	12.0	12.7	13.6
Finland	0	6	7	8	10	11	12	14	15	17	18	20
France	1.2	6.5	6.9	7.2	7.5	7.6	7.7	8.4	8.8	9.4	10.0	10.5
Greece	0.02	1.7	3.3	4.1	4.8	5.6	6.3	7.1	7.8	8.6	9.4	10.1
The Netherlands	0.1	4.1	4.2	4.6	5.1	5.6	6.0	6.8	7.7	8.5	9.4	10.3
Hungary	0.22	3.7	4.6	5.0	5.0	5.2	5.4	5.8	6.4	7.3	8.0	10.0
Ireland	3.1	6.6	8.1	9.0	10.5	11.0	11.8	12.2	12.9	14.0	14.4	16.0
Italy	0.87	3.50	4.12	4.72	5.35	5.98	6.63	7.30	7.98	8.68	9.40	10.14
Latvia	0.9	4	4.1	4.2	4.4	4.5	4.6	5.5	6.3	7.2	8.2	10
Lithuania	0.3	4	4	5	6	6	7	8	9	10	10	10
Luxembourg	0.0	2.1	1.3	1.8	2.4	3.2	3.8	4.4	5.4	6.5	8.3	10.0
Malta	n.a.	2.8	3.0	3.3	3.6	3.9	4.2	4.6	5.8	7.1	8.2	10.7
Poland	n.a.	5.84	6.30	6.76	7.21	7.48	7.73	7.99	8.49	9.05	9.59	10.14
Portugal	0.19	5.0	5.1	5.3	5.7	5.9	8.0	8.2	9.0	9.3	9.7	10.0
United Kingdom	0.2	2.6	3.4	4.0	4.5	5.3	6.2	7.0	7.8	8.6	9.5	10.3
Czech Republic	0.1	4.1	4.6	5.2	5.9	6.5	7.1	7.7	8.3	9.6	10.2	10.8
Romania	1.39	5.82	6.37	6.90	7.32	7.72	8.11	8.43	8.80	9.23	9.69	10.00
Sweden	4.0	7.4	8.1	8.8	9.4	10.1	10.7	11.3	11.9	12.5	13.2	13.8

Source: Cansino et al., 2012

Thus, bioenergy is expected to be the main contributor to the 2020 target, with an anticipated contribution of more than half of the 2020 renewable energy target as an average for the EU MS. The use of bioenergy raises a number of issues relating to sustainability and to their potential for reducing GHG emissions. Articles 16, 17, 18 of the RED set sustainability and compliance criteria for bioliquids and biofuels. Concerning the sustainability of solid biomass used for power and heat production, the RED asks for supplementary explanations from the MS, but the high share of direct wood and agriculture biomass identified in the NREAPs raises concerns about potential conflicts between bioenergy promotion and the limits on the resources available and bioenergy's ability to in reduce GHG emissions (Atanasiu, 2010). In February 2010, the European Commission published a report on sustainability requirements for the use of solid and gaseous biomass for energy production, fulfilling its obligation under Article 17(9) of the RED. Due to the wide variety of biomass feedstocks the Commission considered it infeasible for the moment to put forward a harmonised scheme and binding criteria at EU level (EC, 2010).

Analysts predict that bioenergy (biomass, biogas, bioliquids and biofuels) will contribute close to 55% to the 2020 renewable energy target. This will represent a decrease in relative terms from a 58.9% contribution in 2010 due to a stronger development of other renewable energy sources but an increase in absolute values. Consequently, bioenergy will remain the main contributor to the renewable energy sector. Overall, the share of bioenergy in final energy consumption is expected to more than double, from 5.4% in 2005 to almost 12% in 2020 (e.g., Atanasiu, 2010; Klessmanna et al., 2011; Lau Tuxen, 2010). Appendix 1 provides indicative information on EU supported research, development and demonstration activities and related studies that focused on bioenergy.

1.5 Bioenergy

Bioenergy is energy produced from biomass and all major organisations and countries worldwide define it in a similar way. The UN's Food and Agriculture Organisation (FAO) defines bioenergy as 'all energy derived from biofuels' where biofuels are 'fuels produced directly or indirectly from biomass', considering biomass as 'material of biological origin excluding material embedded in geological formations and transformed to fossil'. The IEA considers bioenergy as the energy produced from 'material which is directly or indirectly produced by photosynthesis and which is utilised as a feedstock in the manufacture of fuels and substitutes for petrochemical and other energy intensive products'. The US Department of Energy considers bioenergy as to be 'the energy derived from biomass' where biomass 'means any organic matter available on a renewable basis, including dedicated energy crops and trees, agricultural crop wastes and residues, wood wastes and residues, and aquatic plants as well as animal, municipal, and other wastes'. Biomass for energy can be used in various ways. Fig. 2 gives a summary of the different options possible. The biomass resources available throughout the European Union can be subdivided into:

- energy crops like short rotation forestry or fast growing reed,
- residues like residual wood from the forest or straw,

- by-products like industrial residual wood or animal manure and
- waste like sewage sludge or demolition wood.

The share of these different biomass fractions in relation to the overall available biomass resource depends on local circumstances. This local dependency is also true for the place where these biomass fractions are available. Accordingly, different biomass streams are available at very different places (i.e. forest, field, industry, waste collection). Most of the existing biomass fractions are characterised by a relatively low energy density. There is a need to harvest or collect them; which might increase the energy density. Because the biomass resources are mostly available where there is no energy demand and vice versa, a supply chain is needed to overcome the gap between the biomass production site and the biomass consumption site. A significant part of the supply chain involves transportation, which can be combined with a mechanical processing step (i.e. compacting, pressing, chipping) to provide a "handy" biomass fuel for more cost efficient transportation and/or storage and/or use process to ensure that the biomass is delivered to the conversion plant upon demand.

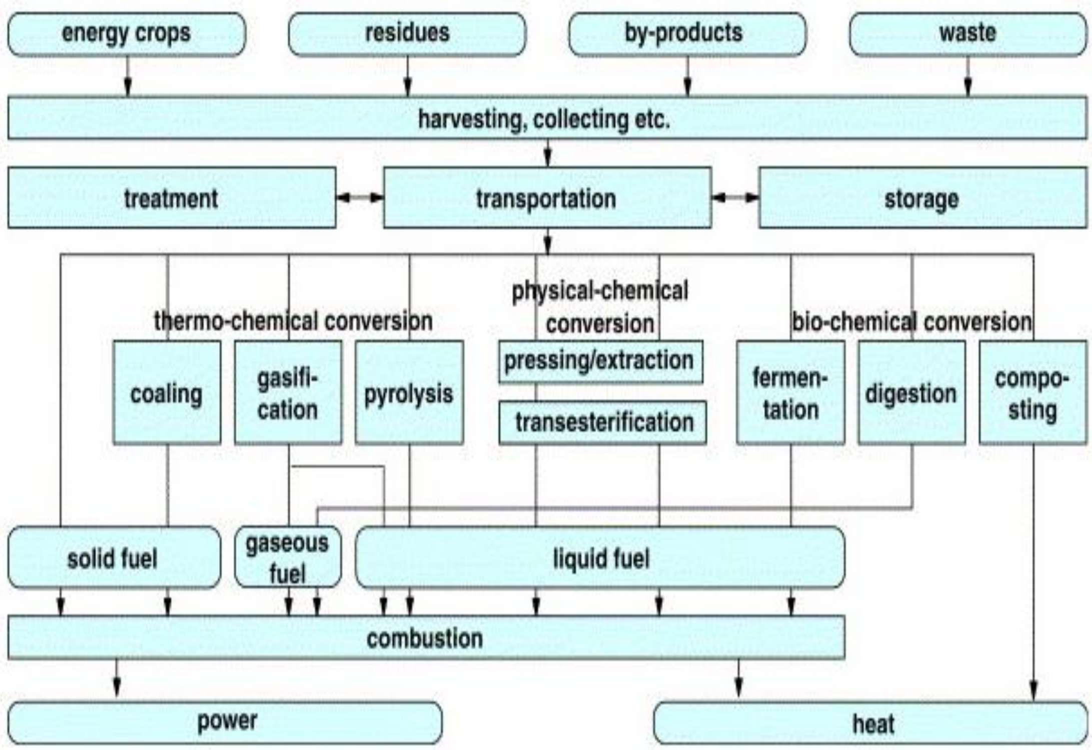

Figure 2: Different options for the conversion of biomass into energy

Source: Kaltschmitt and Webera, 2006

To provide a solid, liquid or gaseous fuel from biomass with defined characteristics treatment of the available biomass streams may be necessary. Different processes are possible depending on the end use technology and the characteristics of the biomass. In general, a distinction is made between thermo-chemical, physical-chemical and bio-chemical conversion processes.

- Thermo-chemical conversion processes convert biomass into a solid, liquid or gaseous fuel, e.g. gasification, pyrolysis and charcoal production. Only charcoal production is a commercial operation and widely used so far. Gasification connected to electricity production seems to be a quite promising option, which might become commercially available within a few years. Compared to this pyrolysis to provide a liquid fuel useable in existing engines is a more or less long-term option.
- A physical-chemical conversion process provides a liquid fuel based on physical (e.g. pressing) and chemical (e.g transesterification) processes. The only important and market mature process is vegetable oil production from oil seeds and the transesterification of this vegetable oil to fatty acid methyl ester (so called Biodiesel) as a substitute for Diesel fuel.
- Bio-chemical conversion is based on biological processes. The most important possibilities are alcohol production from biomass containing sugar, starch and/or celluloses and biogas production from organic waste material (e.g. animal manure). Both technologies are state of the art. Additionally, composting biomass waste can produce energy. But this technology has not been used for energy provision on a commercial scale so far.

Based on these different conversion processes biofuels with clearly defined mechanical and/or chemical fuel characteristics can be produced. These fuels can then be converted in adapted and optimised conversion units (i.e. engines, turbines, ovens) into thermal and/or mechanical energy, which then can be converted into electrical energy.

Solid biofuels for the provision of heat and electricity—as well as liquid fuels for transportation in the longer term—are currently the most important fuels with the highest market impact. Of these possibilities, combustion is most widely used with a large variety of installed thermal capacities ranging from very small stoves up to heating plants with several MW and above. The efficiencies vary significantly between a few percent for simple three stone ovens used in rural areas in developing countries up to approximately 90% and above for technically advanced heating units used in industrialised countries. Electricity generation is based mainly on the conventional steam cycle in the range of electrical capacities of several 100 kW and above

1.5.1 First generation biofuels (conventional)

The term 'first generation biofuels' refers to the fuels that have been derived from sources like starch, sugar, animal fats and vegetable oil. The oil is obtained using the conventional techniques of production. 'First generation' biofuels can offer some CO2 benefits and can help to improve domestic energy security. But concerns exist about the sourcing of feedstocks, including the impact it may have on biodiversity and land use and competition with food crops. A 'first generation' biofuel is characterized either by its ability to be blended with petroleum-based fuels, combusted in existing internal combustion engines, and distributed through existing infrastructure, or by the use in existing alternative vehicle technology like FFVs ("Flexible Fuel Vehicle") or natural gas vehicles. The production of 1st generation biofuels is commercial today, with almost 50 billion liters produced annually (Naik et al., 2010).

However, the first generation biofuels are currently being treated with considerable skepticism. The most sensitive issues are the competition for raw materials (fuel vs. food, feed, fibre or materials) and changes in land use. It has been argued that the competition for biomass feedstock might lead to adverse effects on prices and availability of food and other products such as feed and bio-based materials. Price increases could offer benefits for rural development and communities, but the price effects are likely to have negative effects on the poor that need to buy food. The increased use of land for biofuels crops might lead to changes in land-use, crop displacement, change of crop production patterns, changes in the type of vegetation, deforestation and loss of natural habitats (e.g. Banse et. al., 2011; Eisberg, 2006; Scarlat and Dallemand, 2011). Additionally it is claimed that biodiesel is not a cost efficient emission abatement technology. Therefore, for the abatement of GHG, it is recommended to have more efficient alternatives based on both renewable and conventional technologies (Simpson-Holley et al., 2006). Some of the most popular types of first generation biofuels are:

Bioethanol

Bioethanol is made by conventional fermentation and distillation of sugar and starch. In EU the main feed-stocks are sugar beet, feed-wheat, barley and some. The by-product ("stillage" or "DDGS") is usually used for animal feed. The reform of the sugar regime concentrates sugar beet production in the most efficient areas and allows expansion of production there for ethanol. Bioethanol is produced more cheaply in Brazil from sugar cane, and generally with a better green-house gas (GHG) balance. In US bioethanol is produced from maize with a generally worse GHG balance. Higher blends (10 to 15% ethanol in gasoline) require small car modifications and derogation of hydrocarbon emissions limits. Blends deliver the same car-km for a given energy content as pure gasoline, but ethanol has a lower energy density. Ethanol-rich fuels (85% or more of ethanol) require adapted engines, but can give improved engine efficiency (Edwards et al., 2008).

Biodiesel

Biodiesel meeting fuel specifications is easiest to make from rapeseed (colza), which grows well in Europe. This is separated into oil and cake, which at present is used for animal feed. The oil is reacted with methanol to produce biodiesel (rapeseed methyl ester, RME). However, the glycerine that is being produced as a by-product, amounting to 10% w/w of the biodiesel produced, constitutes a serious waste management issue (Johnson and Takoni, 2007). Rapeseed is already grown in most EU areas where it makes agro/economic sense, but there are limits due to rotation. According to DG-AGRI (2007), the production of rapeseed in EU will only increase slowly despite much higher demand. It is worth noting that increased EU oilseed production can only just keep pace with the foreseen increase in food demand. Therefore EU rapeseed oil is being diverted from the food market, to be replaced by imported oilseeds and oils, particularly the cheaper palm oil.

Compressed Biogas

Anaerobic digestion of wet manure (slurry) and organic waste from food-industry and municipal sources produces methane which, purified, can replace natural gas, and be compressed for road fuel. The existing natural gas grid would be used for distribution, except where the biogas plant is not on the grid. However, the biogas supply is limited by feedstock availability: the marginal source of methane is still natural gas imports. Whichever methane is used for road-fuel, the marginal effect is an increase of natural gas imports. So the marginal GHG benefit of running cars on gas from the grid is the same whether the gas originated from biogas or natural gas. Making biogas itself saves GHG emissions because it avoids methane release from stored manure, but it is more economic to use biogas locally, to generate electricity and heat. This saves the cost of purification, distribution, compression, storage, and vehicle modifications.

1.5.2 Second generation biofuels

Lignocellulosic feedstock can offer the potential to provide novel biofuels, the biofuels of the 'second generation' (Simpson-Holley et al., 2006). Second-generation biofuels produced from 'plant biomass' refers largely to lignocellulosic materials, as this makes up the majority of the cheap and abundant nonfood materials available from plants. But, at present, the production of such fuels is not cost effective because there are a number of technical barriers that need to be overcome before their potential can be realized (Eisberg, 2006). Plant biomass represents one of the most abundant and underutilized biological resources on the planet, and is seen as a promising source of material for fuels and raw materials. At its most basic, plant biomass can simply be burned in order to produce heat and electricity. However, there is great potential in the use of plant biomass to produce liquid biofuels. However, biofuel production from agricultural by-products could only satisfy a proportion of the increasing demand for liquid fuels. This has generated great interest in making use of dedicated biomass crops as feedstock for biofuel production (Gomez et al., 2008).

The examples of 2nd generation biofuels are cellulosic ethanol and Fischer–Tropsch fuels. The production of 2nd generation biofuels is non-commercial at this time, although pilot and demonstration facilities are being developed. Therefore it is anticipated that, these 2nd generation biofuels could significantly reduce CO_2 production, do not compete with food crops and some types can offer better engine performance. When commercialized, the cost of second generation biofuels has the potential to be more comparable with standard petrol, diesel, and would be most cost effective route to renewable, low carbon energy for road transport (Naik et al., 2010).

Therefore due to many advantages and disadvantages of the 1st generation biofuels and obvious advantages of 2nd generation biofuels as shown in Fig. 3, the approaches to integral utilization of biomass for sustainable development are more reasonable, where all parts of the plant such as leaves, bark, fruits, and seeds can be utilized to useful products.

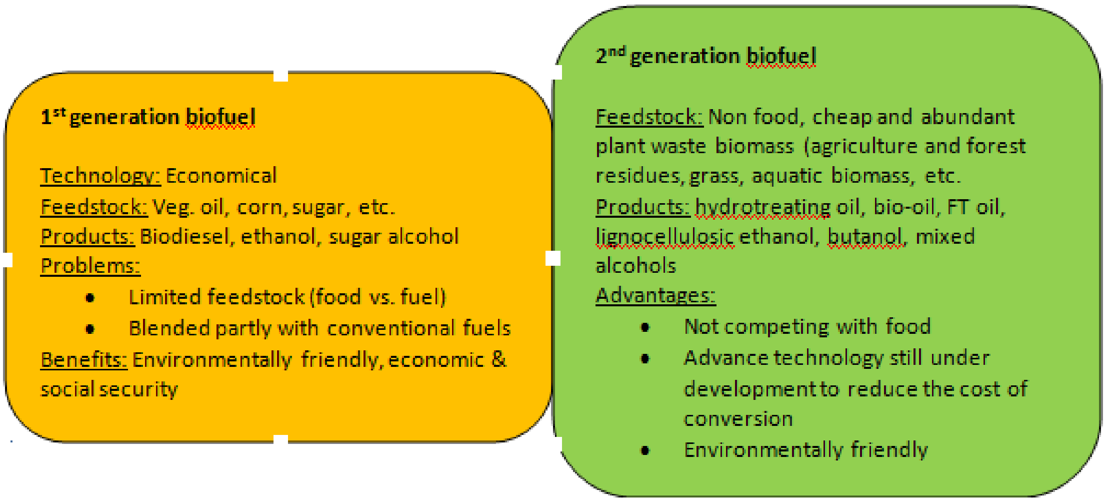

Figure 3: Comparison of first and second generation biofuels

Source: (Adopted from Naik et al., 2010)

1.5.3 Projections for future biofuel demand

Recent estimates by IEA (2010) indicate that 20% of liquid fuel demand by 2050 could be met by biofuels and that, together with low-carbon hydrogen and electricity for vehicles, these will represent approximately 50% of total transport fuels. It should also be noted that this is a downward revision of the previous 2008 IEA ETP (IEA, 2008) which indicated that some 26% of transport fuel demand by 2050 could be from 2G biofuels (IEA, 2008). This downward revision occurred due to the concerns discussed previously over land use and conflicts with food agriculture and land use change (LUC) and the net GHG balances of biofuels, especially those that rely on 1G feedstocks (Fargione et al., 2008; Gallagher Review, 2008; Searchinger et al., 2007). A summary of policies and assessment of the biofuels component of transport fuel requirements from 2010 to 2050 is presented in Table 3.

Table 3: Summary of policies and assessment of the biofuels component of transport fuel requirements (2010 – 2050)

Publication date	Reference	Biofuel proportion in transport fuel
2005	Perlack et al. (2005)	Biomass resource sufficient to replace 30% of US gasoline
2006	Biofuels Research Advisory Council – EU Vision	25% of transport fuel in EU by 2030
2009	EC – Renewable Energy Directive	10% of transport energy as renewable by 2020
2009	EC – Fuel Quality Directive	Potentially increases biofuel to 15% of

Publication date	Reference	Biofuel proportion in transport fuel
		transport energy by 2020
2007	Energy Independence & Security Act 2007 (EPA, 2010a)	7% of expected gasoline & diesel consumption in USA in 2022
2008	Gallagher Review	5 to 8% of transport energy recommended, potentially 10% by 2020
2009	UK Renewable Energy Strategy (Anon, 2009)	10% transport energy by 2020
2008	IEA, 2008 Energy Technology Perspective	26% of total transport fuel demand in 2050
2010	IEA, 2010 Energy Technology Perspective	20% of total liquid fuel demand in 2050

Source: Murphy et al., 2011

1.5.4 Solid biofuels

Solid biofuel is a wide field and includes woody biomass (chips, hogfuel, firewood, wood pellets, briquettes), herbaceous biomass (straw, grass, miscanthus etc.), fruit biomass (olive stones, cherry pits, grape waste, nut shells etc.), as well as a group called 'blends and mixtures'. The definition of solid biofuels excludes all animal-based biomass (e.g. manure, meat and bone meal) and aquatic biomass (such as algae). Demolition timber is considered a hazardous waste and is not included in the solid biofuel category (Kofman, 2010).

Definitions of solid biofuel terms can be found in EN 14588:2010. These terms are used in the EN 14961 standard (please see below), and as such are worth providing:

- Wood chips: chipped woody biomass in the form of pieces with a defined particle size produced by mechanical treatment with sharp tools such as knives.
- Wood pellets: densified biofuel made from pulverized woody biomass with or without additives, usually with a cylindrical form, random length of typically 5 to 40 mm with broken ends.
- Wood briquettes: densified biofuel made with or without additives in the form of cubiform or cylindrical units, produced by compressing pulverized woody biomass.
- Firewood: cut and split oven-ready fuelwood used in household wood burning appliances like stoves, fireplaces and central heating systems. Firewood usually has a uniform length, typically in the range of 150 to 1000 mm.
- Hogfuel: fuelwood in the form of pieces of varying size and shape, produced by crushing with blunt tools such as rollers, hammers, or flails.

Solid biofuels have different degrees of refining. The higher the degree is, the more standardized and predictable the properties. The user has to pay for this, and in return she will get a fuel that can be burned in a combustion plant that requires less work with operation and maintenance. Other advantages with highly refined biofuels are storage capacity and a simpler regulation of the combustion process. Firewood has a low refining degree. In addition to logging and transport, the treatment consists of cutting, chopping and drying. Firewood is poorly suited for automated plants. Bark is considered a waste in the wood processing industry. It contains a high level of ash and is mainly used in large energy production units in connection with industrial plants for debarking of logs. The handling requires a lot of manual work. Wood chips can have a varying degree of refinement. Chip quality will therefore depend on the type of wood, the equipment used for making the chips, sorting techniques and moisture content. Wood chips can be used in all plant sizes, but chips as fuel will normally require more attention and total investment compared to more refined biofuels. Dry chips are a fuel that can be stored, but moist chips start to compost if left too long.

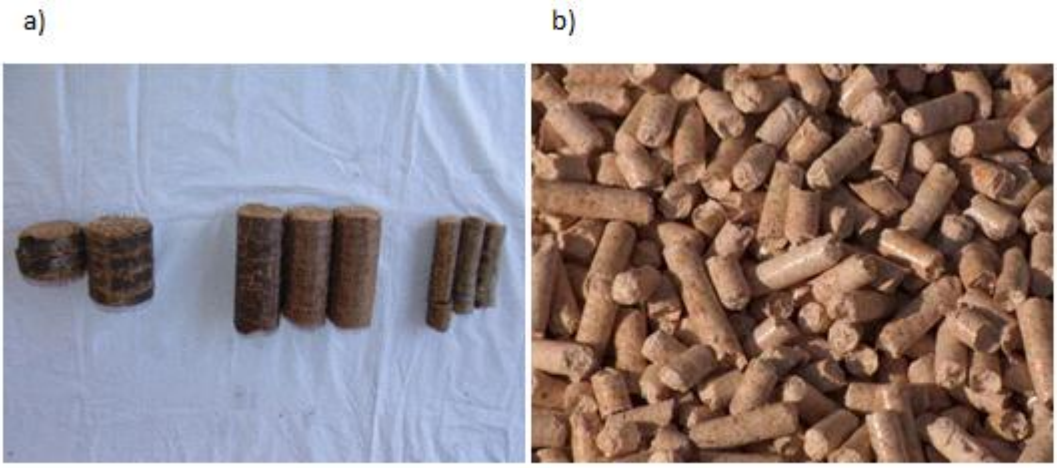

Figure 4: a) Briquettes, b) Pellets

Source: a) Singh et al., 2007; b) Combs et al., 2012

Briquettes are compressed, dried chips from wood or demolition wood (Fig. 4a). The chips are pressed to logs or cylinders with a diameter of 25-70 mm. The length varies up towards 20 cm, depending on the raw material qualities and production processes. Briquetting reduces the volume and makes the fuel more suitable for transport and storage. Briquettes are mainly used in heating plants larger than 1 MW, but also burn well in a wood stove (Singh et al., 2007).

Pellets (Fig 4b) are the solid biofuel that has the highest refining degree. In the same way as briquettes they are compressed chips, but based on a more finely ground raw material and with lengths smaller than 25 mm. Standard diameters are 6, 8 and 12 mm. Pellets are suitable for smaller plants and are normally used up to 1 MW, but in some cases pellets are also used in larger plants. Pellets have properties similar to those of oil with regard to transport, storage and combustion control. Oil-fired plants can often be converted relatively easily for pellet firing (Combs et al., 2012).

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2. QUALITY INDICATORS IN THE SOLID BIOFUEL MARKET

2.1 Markets for solid biofuels

A number of analysts have pointed out that use of solid biofuels within the energy system is currently limited to specific markets. These different markets are characterised by different conditions as well as different fuel requirements and can be subdivided according to the effort to provide a solid fuel with clearly defined fuel characteristics (e.g. Kaltschmitt and Webera, 2006; Pisarek, 2004):

- markets for solid biofuels with low variations of fuel properties (i.e. upgraded fuels like pellets and briquettes),
- markets for biofuels with medium variations of fuel properties (i.e. processed fuels like wood chips), and
- markets for biofuels with high variations of fuel properties (i.e. fuels like wood logs).

These three different markets could additionally be subdivided in markets for small and large scale applications.

2.1.1 Markets for solid biofuels with low variations of fuel properties

Solid biofuels with clearly defined and uniform fuel properties (i.e. fuels with low fuel variations) have to be produced from solid biomass based on an upgrading process. This may be a pelletising process of wood dust or a briquetting process of small woody pieces. Such upgrading processes ensure that the produced solid fuel shows uniform fuel properties. One of the main advantages of such a costly processing step allows the end use technology (pellet stoves) to be optimised according to technical, environmental, economic and other criteria appropriate to the specific fuel properties. Additionally, such a uniform fuel can be traded more easily because the fuel properties are widely known. Besides this, the transportation processes can be optimised and simplified because of the uniform and well known properties and characteristics of the bulk material (Kaltschmitt and Webera, 2006).

The dominant market for this type of biofuel is currently found in the Nordic countries. In Sweden, a total of 94 pellet plants/producers have been identified, producing 1.4 million tonnes of pellets, while the domestic consumption was 1.7 million tonnes, and about 400,000 tonnes of pellets were imported to fulfil the demand in 2007. In Finland, 24 pellet plants/producers have been identified and the production was around 330,000 tonnes while the domestic consumption was 117,000 tonnes in 2007. In Finland, the pellet market has been export oriented for quite some time, whereas domestic consumption has been growing mainly in the small scale consumer sector. An estimated 15,000 households had pellet heating systems in 2008 (Selkimakia et al., 2010).

2.1.2 Markets for solid biofuels with medium variations of fuel properties

Simple mechanical processes produce solid biofuels with medium variations in fuel properties, such as chipping of forest wood to achieve a certain uniformity of the fuel properties according to the given specifications. Such a simple mechanical treatment ensures that the mechanical fuel properties are adjusted compared to untreated wood. But still relatively wide variations of the fuel properties are given compared to upgraded fuels like pellets or briquettes. Nevertheless, such a relatively cheap and simple processing step ensures that bulk material with similar fuel properties is produced, which can be used by the end use technology (i.e. the combustion plant) more or less fully automatic. But a higher technical expenditure is needed compared to, e.g. pellets due to the wider variations within the fuel properties. Compared to fuels with low variations of the fuel properties (like pellets) transportation and storage can be more expensive (due to wider variations of the fuel properties) or easier (because of the lower sensitivity concerning moisture compared to pellets). Compared to fuels with low variations in fuel properties such fuels contribute more to cover the given energy demand within the energy system (Selkimakia et al., 2010).

The main producers of woodchips across the past decade have been Canada (37%), Australia (8%), Sweden (7%), Russia (6%), and China/Finland (each 5%). Global woodchip trade has been partly cross-border (e.g. Finland-Russia, Canada-US) but also heavily driven by Japan (and increasingly China). Across the past decade, Japan has been attracting on average 35%, but in some years over 50% of all globally traded woodchips. The shares of the second largest importers (Canada, Sweden, China, Finland) were below 5% of global trade on average across 2000–2009 (Lamers et al., 2012).

2.1.3 Markets for solid biofuels with high variations of fuel properties

Very simple mechanical provision processes are used to produce solid biofuels with high fuel variations (like wood logs). This could be a simple sawing and cutting of forest wood into pieces. Compared to pellets and wood chips wide variations of the fuel properties occur (i.e. dimension, water content, heating value due to changing bark and/or water content). Such very basic mechanical processing ensures that wood pieces with more or less similar fuel properties are produced which can be used by complex and expensive combustion plants with a high expenditure of human labor or for the necessary fuel preparation and provision of the feeding systems. The technical effort as well as the operation effort is high to meet the given environmental standards (i.e. emission regulations) due to the widely varying fuel properties. Compared to fuels with low or even medium fuel variations transportation is more expensive because the logistics for wood pieces is more time-consuming compared to bulk material. This is also true for the storage of such fuels because a storage facility can be charged and discharged more easily with bulk material compared to wood pieces. This makes wood pieces a relatively expensive fuel if only microeconomic criteria are used. Nevertheless such fuels contribute most to cover the given heat demand especially in rural areas in small-scale systems. The different markets for these fuels are more or less stable with a tendency to decrease (due to the relatively high costs if only microeconomic criteria are used) (Selkimakia et al., 2010).

2.2 Characteristics of solid biofuel quality

Several properties of the fuel contribute to the concept called fuel quality – which affects the usability and value of the fuel. Carbon and hydrogen are mainly the components in biomass which react with oxygen in an exothermic reaction and releases heat, and are therefore the valuable part of the fuel. Fig. 5 presents a typical composition of wood fuels where the moisture content can vary between 10 – 65 % of the weight of the fuel.

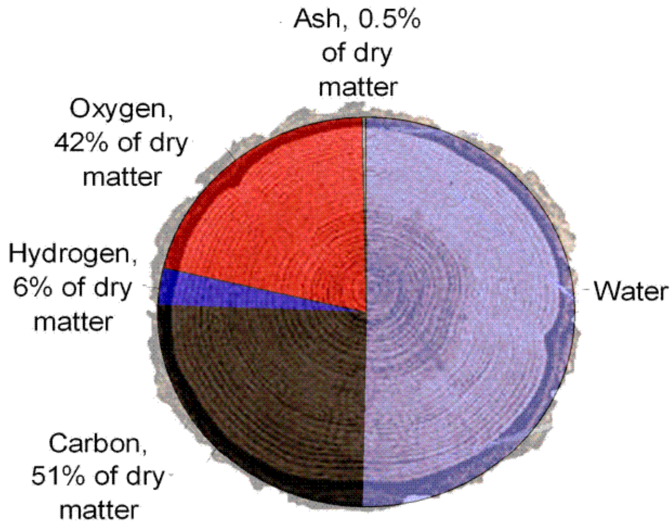

Figure 5: Coarse typical composition of wood fuels. Moisture content can vary between 10 – 65 % of the weight of the fuel

Source: Belbo, 2006

The primary quality requirements governed by the technical limitations of the equipments (e.g. a heating plant or small scale boiler) are requirements of properties like particle size, moisture content and fine fraction. Other quality parameters are those affecting the performance and maintenance costs of the equipment, cost of logistics, air pollution, ash pollution, health and safety for people working with the fuel. The properties of the fuel are affected by growth place, type of wood or herb, handling, processing and storage conditions (Belbo, 2006).

Moisture content and ash content are the factors which most of all affects the calorific value of biofuels. The water in the fuel evaporates during the combustion and binds energy in the vapour. This process lowers the combustion temperature as well as increases the flue gas volume which has to go through the boiler.

Ash is defined as the rest product after combustion and consists of un-combustible inorganic components. Pure wood normally has an ash content of ca 0.3 w-% of dry matter, bark ca 4 w-%, straw materials ca 5 w-%. Variations of ash content in the fuel are mainly caused by treatment, storage conditions and production technique (Belbo, 2006).

Ash deformation contributes to retarded heat transfer and decreased capacity and efficiency of boilers, corrosion in hoppers and grates and in worst case it causes mechanical damages and stoppages in boiler and equipment. A melt that is formed in ash from biomass fuels can belong to either salts of alkali and alkaline metals or oxide/silicate systems (Sasmal et al., 2012).

Sulphur usually forms SO_2 during combustion if sufficient oxygen is present. Sulphur also readily enters into sulphates with most metals if oxygen is available. SO_2 in the flue gas dissolves in water and forms sulphuric acid (H_2SO_4) which is corrosive for the equipment as well as contributes to acid rain. SO_2 may also be captured by calcium to form $CaSO_4$ which is a stable compound and may be separated from the flue gases by filtering (Obernberger et al., 2006; Piotrowska et al., 2011).

Chlorine in the fuel together with alkali metals is highly corrosive for the boiler and tubes, particularly at high temperatures, as these matters undergo chemical reactions into sodium chloride and potassium chloride. Chlorine also may delay the combustion rate and hence increase the concentration of hydrocarbons in the flue gas (Sander, 1997)). Typical sources with high chlorine content is biofuels of agricultural origin, timber floated in the sea and chemically treated wood (Obernberger et al., 2006).

Nitrogen may be oxidized into several oxides during combustion, some of which are NO, NO, NO_3, N_2O_3, N_2O_5 and N_2O. The first five are normally grouped together into “NO_x”, while the latter one, nitrous oxide, is treated separately. The members of the NO_x group all act as acids and thus contribute to corrosion in the boiler and the tubes, as well as, the acid-rain problem. Moreover, nitrous oxide in the first instance is and ozone depleting gas (Walter and Ensinas, 2010).

Nevertheless, biofuel quality can be judged on two basic criteria, which are the chemical and compositional characteristics, as well as, the physical characteristics. Table 4 gives an overview of commonly used parameters, as well as of the effects they have on combustion, conveying, transport or logistics.

It is worth noting that for pellets, during the pelletisation process, it is mainly the physical characteristics of the fuel that are affected. Additionally, both the mean water content and the uniformity of the moisture distribution are drastically improved. The pellet quality cannot be defined without reference to heating technology, since different heating systems require different fuel qualities. For large heating plants durability of pellets and amount of fines is less important, whereas for use in pellet stoves the pellets must be extremely durable so that they do not produce too much dust in the storage bunker and do not cause technical problems in the feeding and combustion unit.

Table 4: General characteristics of biofuel quality

Parameter	Effects
Chemical and compositional characteristics	
Water content	storability, calorific value, losses, self-ignition
Calorific value	fuel utilisation, plant design
Element content	
Cl	HCl, dioxin/furane emissions, corrosion in superheaters
N	NOx, HCN and N2O emissions
S	SOx emissions
K	corrosion in superheaters, reduction of ash melting point
Mg, Ca, P	raising of ash melting point, effect on pollutant retention in ashes and use of ashes
Heavy metals	pollutant emissions, use or disposal of ashes
Ash content	particle emissions, costs for use or disposal of ashes
Ash softening behavior	operational safety, level of pollutant emissions
Fungi spores	health risks during fuel handling
Physical characteristics	
Storage or bulk density	transport and storage expenditures, logistical planning
Unit density	combustion properties (specific heat conductivity, rate of gasification)
Particle size distribution	pourability, bridge-building tendency, operational safety during fuel conveying, drying properties, dust formation
Share of fines	bulk density, transportation losses, dust formation
Durability (for pellets, briquettes)	quality changes during transhipment, disintegration, fuel losses

Source: Hahn, 2004

2.3 The need for standardization

It is widely accepted that the increase in the exploitation of solid biofuels can be achieved through the reduction in the costs of energy provision. Logic dictates that decreased costs will result in increases in the use of biomass by the energy industry. A caveat is that the cost reduction has to be realised throughout the overall provision chain. This means biomass production, provision of the solid biofuels, thermochemical and energetic use, as well as, ash utilisation and disposal. In addition, the non-technical barriers preventing the increased use of biofuels will also have to be overcome (e.g. partly strongly varying fuel characteristics, security of supply).

A standardisation of characteristic values of solid biofuels describing the combustion behavior as well as the methods and procedures for their determination is an important supporting measure, under various other measures, to reach the goals outlined above. If this goal is to be achieved, then the following effects can be expected:

- The producers of solid biofuels will have a clear goal (i.e. well known and clear defined threshold values) to be fulfilled during the production and provision of their solid fuels. Based on the secure fulfillment of these pre-defined fuels requirements they can provide fuels with a well known quality and can optimise their production and provision processes to reduce the overall provision costs.

- Bases on pre-defined (i.e. standardised) fuel specifications accepted by the various players on the market throughout the overall provision chain a regional, national and international market can be developed. This is true because the characteristic of the solid fuel "wood pellet" or "wood chip" are well known (this is the same as with the characteristics of conventional Diesel fuel where the parameters defining the fuel are globally defined). Such a well known definition of the fuel characteristic will lead additionally to a better transparency within the market and on the pricing.

- Based on clear, commonly recognised and binding defined fuel characteristics the producer of plants, processes and products as well as machinery and equipment for the production and provision of solid biofuels on the one hand side, as well as, combustion units on the other side, can optimise their products efficiently with respect to the pre-defined fuel characteristics. Additionally, the conversion devices can be optimised for the predefined fuel characteristics to minimise the emissions of unwanted substances responsible for legal emission limits. The result of such a development will be the availability of combustion units optimised to well known solid biofuel classes according to technical, economic and environmental aspects.

2.4 Standards for solid biofuels

As mentioned above, quality standards can ensure customer satisfaction and encourage market dissemination of biofuels by:

- guaranteeing a common, official, national quality of fuel pellets, heating equipment, transport and storage,

- ensuring legal compliance and security for all involved market actors by defining responsibilities and duties,

- helping to overcome and harmonize friction points along the supply chain by defining special quality indicators and limit values,

- informing the final consumers about quality characteristics.

Although several national standards are in existence, this chapter will solely focus on the standards that have been developed by the EU.

2.4.1 EN 14961 series

The main standards in the area of biomass fuels in the EU are the EN 14961 series. The series describe the origin of the fuel, the traded form, and for each fuel gives a list of properties and the classes into which these properties are divided. In Part 1, general requirements, quality demands are not formulated as such, but for each property a list of classes is given and how each class is delimited. In parts 2 to 6, quality classes are given for specific fuels (like wood pellets, briquettes, wood chips, firewood, non woody pellets) and the criteria to which that fuel must comply with to belong to a certain quality class. More details for each of the series are provided below. The text presented below is drawn from two main sources (unless otherwise stated). These sources are Kofman, 2010 (Preview of European standards for solid biofuels) and Comitato Termotecnico Italiano Energia E Ambiente (Guide to Biomass Heating Standards: Ensuring quality and reliability in the biomass heating supply chain).

EN 14961 - 1 Solid biofuels. Fuel specifications and classes. Part 1: General requirements

This part explains how to classify the biomass to be used for energy purposes and lists the major traded forms of solid biofuels (Table 5). The standard contains two main tables. The first table specifies the origin of the biomass and explains the shape in which biomass can be traded (Table 6). The second table explains the main dimensions and how the material is processed. These two main tables are followed by twelve products specific tables, listing the properties of the particular solid biomass. If a fuel is not listed as one of the 12 specific fuels, a final table of properties can be used for general application. In all cases, a range of classes is given for each property. For example, for moisture content the range starts with M10 which means that the product should contain less than 10% moisture.

Table 5: Major traded forms of solid biofuels

Fuel name	Common preparation method
Whole tree	No preparation or delimbed
Wood chips	Cutting with sharp tools
Hog fuel	Crushing with blunt tools
Log wood/firewood	Cutting with sharp tools
Bark	Debarking residue from trees Can be shredded or unshredded
Bundle	Lengthways oriented & bound
Fuel powder	Milling
Sawdust	Cutting with sharp tools
Shavings	Planing with sharp tools
Briquettes	Mechanical compression
Pellets	Mechanical compression
Bales, Small or big square bales, Round bales	Compressed and bound to squares Compressed and bound to squares Compressed and bound to cylinders
Chopped straw or energy grass	Chopped during harvesting or before combustion
Grain or seed	No preparation or drying except for process operations necessary for storage for cereal grain
Fruit stones or kernel	No preparation or pressing and extraction by chemicals.
Fibre cake	Prepared from fibrous waste by dewatering

Source: CTIA

Table 6: Classification of origin and sources of Woody biomass

1.1. Forest and plantation wood	1.1.1. Whole trees	1.1.1.1. Deciduous
		1.1.1.2. Coniferous
		1.1.1.3. Short rotation coppice
		1.1.1.4. Bushes
		1.1.1.5. Blends and mixtures
	1.1.2. Stemwood	1.1.2.1. Deciduous
		1.1.2.2. Coniferous
		1.1.2.3. Blends and mixtures
	1.1.3. Logging residues	1.1.3.1. Fresh/Green (including leaves/needles)
		1.1.3.2. Dry
		1.1.3.3. Blends and mixtures
	1.1.4. Stumps	1.1.4.1. Deciduous
		1.1.4.2. Coniferous
		1.1.4.3. Short rotation coppice
		1.1.4.4. Bushes
		1.1.4.5. Blends and mixtures
	1.1.5. Bark (from forestry operations)a	-
	1.1.6. Landscape management woody biomass	-
1.2. Wood processing industry, by-products and residues	1.2.1. Chemically untreated wood residues	1.2.1.1. Without bark
		1.2.1.2. With barka
		1.2.1.3. Bark (from industry operations)a
		1.2.1.4. Blends and mixtures
	1.2.2. Chemically treated wood residues	1.2.2.1. Without bark
		1.2.2.2. With barka
		1.2.2.3. Bark (from industry operations)a
		1.2.2.4. Blends and mixtures
	1.2.3. Fibrous waste from the pulp and paper industry	1.2.3.1. Chemically untreated fibrous waste
		1.2.3.2. Chemically treated fibrous wasteb

1.3. Used wood	1.3.1. Chemically untreated wood	1.3.1.1. Without bark
		1.3.1.2. Barka
		1.3.1.3. Blends and mixtures
	1.3.2. Chemically treated woodb	1.3.2.1. Without bark
		1.3.2.2. Barka
		1.3.2.3. Blends and mixtures
1.4. Blends and mixtures		

Source: Alakangas et al., 2006

EN 14961 - 2 Solid biofuels. Fuel specifications and classes. Part 2: Wood pellets for non-industrial use

Stringent quality requirements have been formulated for wood pellets: for stoves and small boilers class A pellets; while for the larger boilers up to 500 kW, class B pellets with slightly lower quality requirements. Important properties of wood pellets are the origin of the base material, the ash content, the durability and the chlorine content. 1 class pellets have to be produced from either sawdust or from debarked roundwood. These materials have a low chemical content. Pellets in the A2 class may be produced from materials containing bark, while B class pellets may also contain by-products from board and paper mills as well as clean, used wood. Since most stoves or small boilers do not have automatic de-ashing, it is important that the ash content of wood pellets is as low as possible. With a low ash content, one should only have to remove the ash once a week. So for Class A1 and A2 there is a low ash content, while for class B, which is meant for larger boilers with automatic de-ashing, a higher ash content can be tolerated. Pellets endure a lot of wear from the moment they are produced until they arrive in the boiler. Wear produces fines, which have a different burning characteristic to whole pellets. If the fines content gets too large, the boiler will burn hotter than usual and the ash might form clinker. Therefore pellet durability should be in excess of 97.5%, meaning that the pellets can withstand normal handling without falling apart. The chlorine content of the wood pellets is important, because the increased risk of corrosion with an increased amount of chlorine in the pellets.

EN 14961 - 3 Solid biofuels. Fuel specifications and classes. Part 3: Wood briquettes for non-industrial use

This standard is very similar to the pellets standard with the quality classes A and B. In the briquette standard the durability test has been replaced by a measurement of the basic density. Briquettes do not sustain as much wear as wood pellets.

EN 14961 - 4 Solid biofuels. Fuel specifications and classes. Part 4: Wood chips for non-industrial use

Quality requirements have been formulated for wood chips. Property classes A1 and A2 represent virgin wood and chemically untreated wood residues. A1 represents fuels with lower ash content indicating no or little bark, and a lower moisture content, while class A2 has slightly higher ash content and/or moisture content. B1 extended the origin and source of class A to include other material, such as short rotation coppice, wood from gardens etc., and chemically untreated industrial by-products and residues. Property class B2 also includes chemically treated industrial byproducts and residues and used wood, but without harmful chemicals or heavy metals. For wood chips the most important issues are the moisture content, the size distribution and the ash content. The moisture content more or less dictates the type of boiler in which the chips can be used. Small boilers need a dry fuel, while the larger boilers can often work with a higher moisture content. Since boilers up to 500 kW usually are fed with an auger, it is important that the chips are of an even size and do not contain too many oversized particles. Long thin particles might bridge over the intake opening of the fuel and prevent it from entering the boiler. Blocky oversized pieces can get stuck in the auger and prevent it from feeding fuel to the boiler. Small boilers usually do not have automatic de-ashing and thus it is important to have a low ash content in the fuel, which is the case in the class A fuels. Larger boilers usually have automatic de-ashing and so can tolerate the B class fuel with a higher ash content is tolerated. The main parameters to be considered for non-industrial pellets and woodchips (EN 14961 – 2 & 4) are listed in Table 7.

EN 14961 - 5 Solid biofuels. Fuel specifications and classes. Part 5: Firewood for non-industrial use

The standard assumes that combustion-ready firewood is being traded. In case the wood is not seasoned enough, the standard can still be used but the actual moisture content shall be indicated. The moisture content is the most important issue for firewood. Wood should be seasoned properly before being used, to prevent pollution due to unburned gasses, the buildup of running soot in the chimney and the emission of fine dust. Since most stoves and small boilers have a relatively small burning chamber, the length and diameter of the logs is also important. In addition, the amount of split wood is important, because splitting helps in the seasoning of the wood.

EN 14961 - 6 Solid biofuels. Fuel specifications and classes. Part 6: Non woody pellets for non-industrial use

Table 7: Key parameters for non-industrial pellets and woodchips according with EN 14961-2 and 4 *(continues below)*

Parameter	**Meaning**	**Notes for Pellet**	**Notes for Wood Chip**
Origin and source:	It has to be clearly stated according with the different sources allowed by each standards.		
Diameter for pellet or Dimension for chips	It is a physical value that could influence the plant/appliance feeding system.	For pellet diameter could vary from 6 to 8 mm ± 1 mm. A higher diameter could affect the correct functioning of the stove.	The dimension is important for the appliance feeding systems; it also could lead to bridging phenomena in the bulk storage
Moisture:	This parameter mainly affect the energy content and the storage. Moreover it is often used to define the contractual price of the biofuel.	It has to be lower than 10% since an higher content could scale and damage the pellet.	It is on of the key parameter for the chips. For class A moisture could vary up to 35%.
Ash:	Ashes are the mineral residues remaining after a complete combustion. Their amount has to be as low as possible. An high value means bad quality of biomass or a bad management during the production of the biofuel. An high ash content leads to a more frequent maintenance of the plant/appliance/boiler (removing of ashes in the combustion chamber or cleaning of the glasses).	High quality pellet (A1) shall have an ash content lower than 0.7%. A2 class allows a higher (up to 1.5%) ash content, while B admits and ash content up to 3%.	Ash content for wood chips is approached in a similar way as the pellet

Table 7: Key parameters for non-industrial pellets and woodchips according with EN 14961-2 and 4 *(continues from above)*

Parameter	**Meaning**	**Notes for Pellet**	**Notes for Wood Chip**
Mechanical durability	It represents the capability of pellets to resist to crumble and break down to sawdust. It is one of the main requirements for pellet since affects its storability and integrity especially if pellet is subjected to several handling steps	It has to be the highest, more than 97.5 %	Not relevant
Fines at factory gate	It represents the percentage of sawdust in the package. Sawdust can't be handled by the feeding systems of pellet appliances.	It has to be the lowest; no more that 1% is allowed.	Not relevant
Additives	Additives are materials which should improve the efficiency of pellet production. Pellet producers generally use starch, corn or potato flour, vegetable oil.	Type and amount have to be clearly stated. In any case a maximum amount of 2% is allowed.	Not relevant
Net calorific value	It represents the energy content of the biofuel and is strongly connected with moisture content. Attention has to be paid for the unit used to declare this parameter. A typical mistake is to declare the gross value instead of the net, giving an overestimation of the fuel energy content.	An high calorific value could mean that pellet is made by other material than wood (plastics, glues, etc.),	
Bulk density	It is a key parameter since allows to calculate "quantities". It represents the weight (mass) of the bulk for unit of volume.	It has to be higher than 600 kg/m^3	It has to be higher than 150-200 $kg/^{m3}$
Nitrogen, Sulphur, Chlorine, Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Zinc	Chemical compounds/elements have to be considered indicators of possible contaminants of the original biomass. For this reason higher contents than expected can indicate a pollution (voluntary or involuntary) of the raw material.		

2.4.2 Standards for fuel production, transport and storage

The EN 15234 series on "fuel quality assurance" has been formulated to deal with the production, transport and the handling of biofuels, which are important parts of the supply chain. These Standards are based on the same approach used for the EN ISO 9001 "Quality management systems Requirements", and are thus easily applicable by the larger operators involved in biofuel production. The key standards in this series are briefly explained below.

- EN 15234-1 Solid biofuels - Fuel quality assurance - Part 1: General requirements
- EN 15234-2 Solid biofuels - Fuel quality assurance - Part 2: Wood pellets for non-industrial use
- EN 15234-3 Solid biofuels - Fuel quality assurance - Part 3: Wood briquettes for non-industrial use
- EN 15234-4 Solid biofuels - Fuel quality assurance - Part 4: Wood chips for non-industrial use
- EN 15234-5 Solid biofuels - Fuel quality assurance - Part 5: Firewood for non-industrial use
- EN 15234-6 Solid biofuels - Fuel quality assurance - Part 6: Non-woody pellets for non-industrial use

The general part of this set (EN 15234-1) defines the procedures to fulfil the quality requirements of solid biofuels and describes measures to ensure adequate confidence that the biofuel specifications (EN 14961 series) are fulfilled. This European Standard covers the whole chain, from supply of raw materials to point of delivery to the end-user, while the quality assurance systems applied to the operation of conversion plants fuelled by solid biofuels are outside the scope of the standard. Moreover even if health, safety and environmental issues for solid biofuels are important and need special attention, they are outside the scope as well. By applying this standard it is possible to ensure traceability and to demonstrate that all the processes along the biofuel supply chain (please see also section 3) up to the point of the delivery to the end user are under control, thus the final quality of the product is assured. The other five parts of the EN 15234 series deal with specific requirements for pellets, briquettes, chips, firewood and non woody pellets.

2.4.3 Standards for boilers

Another important category that should be briefly mentioned is the boiler itself. Boilers are covered by:

- EN 303-5 - Part 5: Heating boilers for solid fuels, hand and automatically stoked, nominal heat output of up to 500 kW - Terminology, requirements, testing and marking.

EN 303-5 applies to heating boilers up to a nominal heat output of 500 kW, which are designed for the burning of solid fuels only and are operated according to the instructions of the boiler manufacturer. Boilers can have natural draught or forced draught and the stoking can be manual or automatic.

This standard covers only boilers including burners as a unit and not simpler appliances as fireplaces or pellet stoves. Solid fuels to be used according to this standard are:

- Biogenic fuels (biomass) in a natural state in the form of:
    - Log wood with water content w ≤ 25 %;
    - Chipped wood (wood chipped by machine with and without bark, usually up to a maximum length of 15 cm) water content from 15 % to 35 % or more;
    - Compressed wood (pellets without binding agents, made of wood and/or bark particles; permitted are natural binding agents such as molasses, vegetable paraffins and starch); Pellets according to EN 14961-2;
    - Compressed wood (briquettes without binding agents, made of wood and/or bark particles; permitted are natural binding agents such as molasses, vegetable paraffins and starch); Briquettes according to EN 14961-3;
    - Sawdust up to w 50 % moisture;
    - Non woody biomass such as straws, reeds, kernels and grains.
- Fossil fuels
    - Bituminous coal;
    - Brown coal;
    - Coke;
    - Anthracite.
- Other solid fuels (e.g. peat)

The standard contains requirements and test methods for safety, combustion quality and efficiency, operating characteristics and maintenance of heating boilers, and covers also all external equipment that influences the safety systems (e.g. backburn safety device, integral fuel hopper).

An interesting section of EN 303-5 is represented by a classification scheme based on emission levels. One of the main requirements of the Standard is that combustion shall be ‘low-emission’. This is satisfied if emission values do not exceed some defined thresholds for Carbon Monoxide (CO), Dust/particulate matter and Organic Gaseous Compounds (OGC)

2.5 Example of the classification of wood fuels

2.5.1 Wood briquettes

What follows is an example for high quality wood briquettes recommended for household usage (Alakangas et al., 2006).

- Origin: 1.2.1.1 Chemically untreated wood, wood excluding bark (Table 6)
- Moisture content: M10 (moisture<10 wt%)
- Particle density: DE1.0 (1.00–1.09 kg/dm3)
- Dimensions: to be selected from Table 8.
- Ash content: A0.7 wt% (<0.7 wt% of dry matter)
- Additives<2 wt% of dry basis. Only products from the primarily agricultural and forest biomass that are not chemically modified are approved to be added as a pressing aids. Type and amount of additive has to be stated.
- Net calorific value: E4.7 [kWh/kg] (Ear⩾4,7 kWh/kg=16.9 MJ/kg)

Table 8: Dimensions for briquettes (mm)

Diameter (D), mm		**Length (L), mm**	
D40	25⩽*D*⩽40	L50	⩽50
D50	⩽50	L100	⩽100
D60	⩽60	L200	⩽200
D80	⩽80	L300	⩽300
D100	⩽100	L400	⩽400
D125	⩽125	L400+	⩾400 actual value to be stated
D125+	⩾125 actual value to be stated		

Source: Alakangas et al., 2006

2.5.2 Wood pellets

What follows is an example for high quality wood pellets recommended for household usage (Alakangas et al., 2006).

- Origin: Chemically untreated tree without bark (1.2.1.1)(Table 6)
- Moisture content: M10 (moisture<10 wt%)

- Mechanical durability: DU97.5 (97.5 wt% of a pellet batch of 100 g shall be uncrushed after testing)

- Percentage of fines: F1.0 or F2.0 (percentage of fines among pellets sieved through <3.15 mm sieve shall not exceed 1 or 2 wt% at factory gate)

- Dimensions: D06 or D08 (pellet diameter 6 mm±0.5 mm and length<5×diameter or diameter 8±0.5 mm, and length<4×diameter). Maximum 20 wt% of the pellets may have a length of 7.5×diameter

- Ash content: A0.7 (<0.7 wt% of dry matter)

- Sulphur content: S0.05(<0.05 wt% of dry matter)

- Additives: <2 wt% of dry matter may consist of bio-based chemically untreated material, the type and amount to be given

- Net calorific value: E4.7 [kWh/kg] (net calorific value>4.7 kWh/kg=16.9 MJ/kg).

Table 9 below provides an overview of European and international standards on solid biofuels. Appendix 2 includes a list of national standardization bodies.

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Table 9: European standards and international standards on solid biofuels *(continues below)*

European standards (EN) *If dated, the (draft) standard is published and publicly available*		International standards (ISO) *If dated, the (draft) standard is published and publicly available*	
Terminology		**Terminology**	
EN 14588:2010	Solid biofuels – Terminology, definitions and descriptions	ISO/CD 16559	Solid biofuels -- Terminology, definitions and descriptions
Fuel specifications and classes		**Fuel specifications and classes**	
EN 14961-1:2010	Solid biofuels – Fuel specifications and classes – Part 1: General requirements	ISO/CD 17225-1	Solid biofuels -- Fuel specifications and classes -- Part 1: General requirements
EN 14961-2:2011	Solid biofuels – Fuel specifications and classes – Part 2: Wood pellets for non-industrial use	ISO/CD 17225-2	Solid biofuels -- Fuel specifications and classes -- Part 2: Graded wood pellets
EN 14961-3:2011	Solid biofuels – Fuel specifications and classes – Part 3: Wood briquettes for non-industrial use	ISO/CD 17225-3	Solid biofuels -- Fuel specifications and classes -- Part 3: Graded wood briquettes
EN 14961-4:2011	Solid biofuels – Fuel specifications and classes – Part 4: Wood chips for non-industrial use	ISO/CD 17225-4	Solid biofuels -- Fuel specifications and classes -- Part 4: Graded wood chips
EN 14961-5:2011	Solid biofuels – Fuel specifications and classes – Part 5: Firewood for non-industrial use	ISO/CD 17225-5	Solid biofuels -- Fuel specifications and classes -- Part 5: Graded firewood
EN 14961-6:2012	Solid biofuels – Fuel specifications and classes – Part 6: Non-woody pellets for non-industrial use	ISO/CD 17225-6	Solid biofuels -- Fuel specifications and classes -- Part 6: Graded non-woody pellets

Table 9: European standards and international standards on solid biofuels *(continues below)*

European standards (EN)		International standards (ISO)	
If dated, the (draft) standard is published and publicly available		*If dated, the (draft) standard is published and publicly available*	
		ISO/CD 17225-7	Solid biofuels -- Fuel specifications and classes -- Part 7: Graded non-woody briquettes
Fuel quality assurance		**Fuel quality assurance**	
EN 15234-1:2011	Solid biofuels – Fuel quality assurance – Part 1: General requirements	ISO/NP 17588	Solid biofuels -- Fuel quality assurance
EN 15234-2:2012	Solid biofuels – Fuel quality assurance – Part 2: Wood pellets for non-industrial use		
EN 15234-3:2012	Solid biofuels – Fuel quality assurance – Part 3: Wood briquettes for non-industrial use		
EN 15234-4:2012	Solid biofuels – Fuel quality assurance – Part 4: Wood chips for non-industrial use		
EN 15234-5: 2012	Solid biofuels – Fuel quality assurance – Part 5: Firewood for non-industrial use		
EN 15234-6: industrial use	2012 Solid biofuels – Fuel quality assurance – Part 6: Non-woody pellets for non-		
		ISO/NP 17589	Solid biofuels -- Conformity assessment for fuel quality assurance

Table 9: European standards and international standards on solid biofuels *(continues below)*

European standard		International standard	
Sample and sample preparation		**Sample and sample preparation**	
EN 14778:2011	Solid biofuels – Sampling	ISO/NP 18135	Solid biofuels -- Sampling
EN 14780:2011	Solid biofuels – Sample preparation	ISO/NP 14780	Solid biofuels -- Sample preparation
Physical and mechanical properties		**Physical and mechanical properties**	
EN 14774-1:2009	Solid biofuels – Determination of moisture content – Oven dry method – Part 1: Total moisture – Reference method	ISO/NP 18134-1	Solid biofuels -- Determination of moisture content -- Oven dry method -- Part 1: Total moisture -- Reference method
EN 14774-2:2009	Solid biofuels – Determination of moisture content – Oven dry method – Part 2: Total moisture – Simplified method	ISO/NP 18134-2	Solid biofuels -- Determination of moisture content -- Oven dry method -- Part 2: Total moisture - Simplified method
EN 14774-3:2009	Solid biofuels – Determination of moisture content – Oven dry method – Part 3: Moisture in general analysis sample	ISO/NP 18134-3	Solid biofuels -- Determination of moisture content -- Oven dry method -- Part 3: Moisture in general analysis sample

Table 9: European standards and international standards on solid biofuels *(continues below)*

European standards (EN)		International standards (ISO)	
If dated, the (draft) standard is published and publicly available		*If dated, the (draft) standard is published and publicly available*	
EN 14775:2009	Solid biofuels – Determination of ash content	ISO/NP 18122	Solid biofuels -- Determination of ash content
EN 14918:2010	Solid biofuels – Determination of calorific value	ISO/NP 18125	Solid biofuels -- Determination of calorific value
EN 15103:2010	Solid biofuels – Determination of bulk density	ISO/NP 17828	Solid biofuels -- Determination of bulk density
EN 15148:2009	Solid biofuels – Determination of the content of volatile matter	ISO/NP 18123	Solid biofuels -- Determination of the content of volatile matter
EN 15149-1:2010	Solid biofuels – Determination of particle size distribution – Part 1: Oscillating screen method using sieve apertures of 1 mm and above	ISO/NP 17827-1	Solid biofuels -- Determination of particle size distribution for uncompressed fuels -- Part 1: Horizontally oscillating screen using sieve for classification of samples with a top aperture of 3.15 mm and above
EN 15149-2:2010	Solid biofuels – Determination of particle size distribution – Part 2: Vibrating screen method Rotary screen method using sieve apertures of 3,15 mm and below		
CEN/TS 15149-3:	2006 Solid Biofuels – Methods for the determination of particle size distribution – Part 3:		
EN 15150:2011	Solid biofuels – Determination of particle density		
EN 15210-1:2010	Solid biofuels – Determination of mechanical durability of pellets and briquettes – Part 1: Pellets	ISO/NP 17831-1	Solid biofuels -- Methods for the determination of mechanical durability of pellets and briquettes -- Part 1: Pellets
EN 15210-2:2010	Solid biofuels – Determination of mechanical durability of pellets and briquettes – Part 2: Briquettes	ISO/NP 17831-2	Solid biofuels -- Methods for the determination of mechanical durability of pellets and briquettes -- Part 2: Briquettes
EN 16126:2012	Solid biofuels – Determination of particle size distribution of disintegrated pellets	ISO/NP 17830	Solid biofuels -- Determination of particle size distribution of disintegrated pellets
EN 16127:2012	Solid biofuels – Determination of length and diameter for pellets and cylindrical briquettes	ISO/NP 17829	Solid biofuels -- Determination of length and diameter of pellets

Table 9: European standards and international standards on solid biofuels *(continues from above)*

Chemical analysis		**Chemical analysis**	
EN 15104:2011	Solid biofuels – Determination of total content of carbon, hydrogen and nitrogen – Instrumental methods	ISO/NP 16948	Solid biofuels -- Determination of total content of carbon, hydrogen and nitrogen
EN 15105:2011	Solid biofuels – Determination of the water soluble chloride, sodium and potassium content		
EN 15289:2011	Solid biofuels – Determination of total content of sulfur and chlorine	ISO/NP 16994	Solid biofuels -- Determination of total content of sulphur and chlorine

European standards (EN) *If dated, the (draft) standard is published and publicly available*		**International standards (ISO)** *If dated, the (draft) standard is published and publicly available*	
EN 15290:2011	Solid biofuels – Determination of major elements – Al, Ca, Fe, Mg, P, K, Si, Na and Ti	ISO/NP 16967	Solid biofuels -- Determination of major elements
EN 15296:2011	Solid biofuels – Conversion of analytical results from one basis to another	ISO/NP 16993	Solid biofuels -- Conversion of analytical results from one basis to another
EN 15297:2011	Solid biofuels – Determination of minor elements – As, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Sb, V and Zn	ISO/NP 16968	Solid biofuels -- Determination of minor elements
ISO/NP 16996	Solid biofuels -- Determination of elemental composition by X-ray fluorescence		

Source: Solid Standards Project, 2012

3. COST BENEFIT ANALYSIS BASED ON QUALITY CONTROL AT SPECIFIC POINTS IN THE SOLID BIOFUEL SUPPLY CHAIN

3.1 Quality Management

As has been outlined in previous sections, one of the key energy goals of the EU is the increased penetration of biofuels into the energy mix. In this respect, the creation of a dynamic and sustainable Europe-wide market for biofuels that will create competition (and thus, help reduce prices) is imperative. The standardisation of some biofuel properties (outlined in section 2) paves the way for the provision of information and tools that will eventually facilitate businesses transactions and thus, will help define the market rules for the different players. As an example, the standardisation of pellets was one of the driving forces that enabled the substantial market growth that was witnessed in the last decade since the pellet producer, the manufacturers of boilers and the end-users could benefit from the fact that the fuel properties are clearly defined.

However, gaining the confidence and trust of customers within this market requires a demonstrable high level of quality for both biofuels and the combustion devices used. This is particularly important for the fuel quality, which can be influenced by various factors that are determined by the technology used throughout the overall supply chain, and even more by management. In general it is essential, that the demanded fuel quality—either it follows a standard or site specific customer needs—as well as other requirements of the customer are fulfilled. Thus, adequate controls should be ensured throughout the overall supply chain through the application of a Quality Management (QM) system with main focus on Quality Assurance (QA) and Quality Control (QC).

The complexity of the supply chain of solid biofuels makes this a difficult task. Figure6 aims to demonstrate some of the different types of solid biofuel supply chains and appropriate points for documenting the origin and source and the points for making the product declaration. Figure 6 is only listing operators and documentation (not harvesting, transport or storage processes).

Moreover, companies dealing with solid biofuels throughout the overall chain also cover a wide range of competences. Some of them buy raw biomass, such as residues from agriculture and/or forestry, and convert them into higher-grade biofuels for the sale to third parties. Others buy solid biofuels for the production of electricity and heat for sale. Examples of both types (as well as intermediate cases) play key roles in the expanding market for solid biofuels.

At the European level, the standard that applies is the EN 15234-1:2011, “Fuel Quality Assurance” that has been produced by the Technical Committee from the European Standardisation Organisation (CEN) (Table 9). However, only one report dealing with QM for solid biofuels has been found in the literature. The work deals with the guidelines and methodology on how to develop and implement a QA system within a company dealing with solid biofuels. It has been developed during the BIONORM (ENK6-CT-2001-00556) project and is reported by Langheinrich and Kaltschmitt, 2006. As a result the present chapter has based on this work, unless otherwise stated.

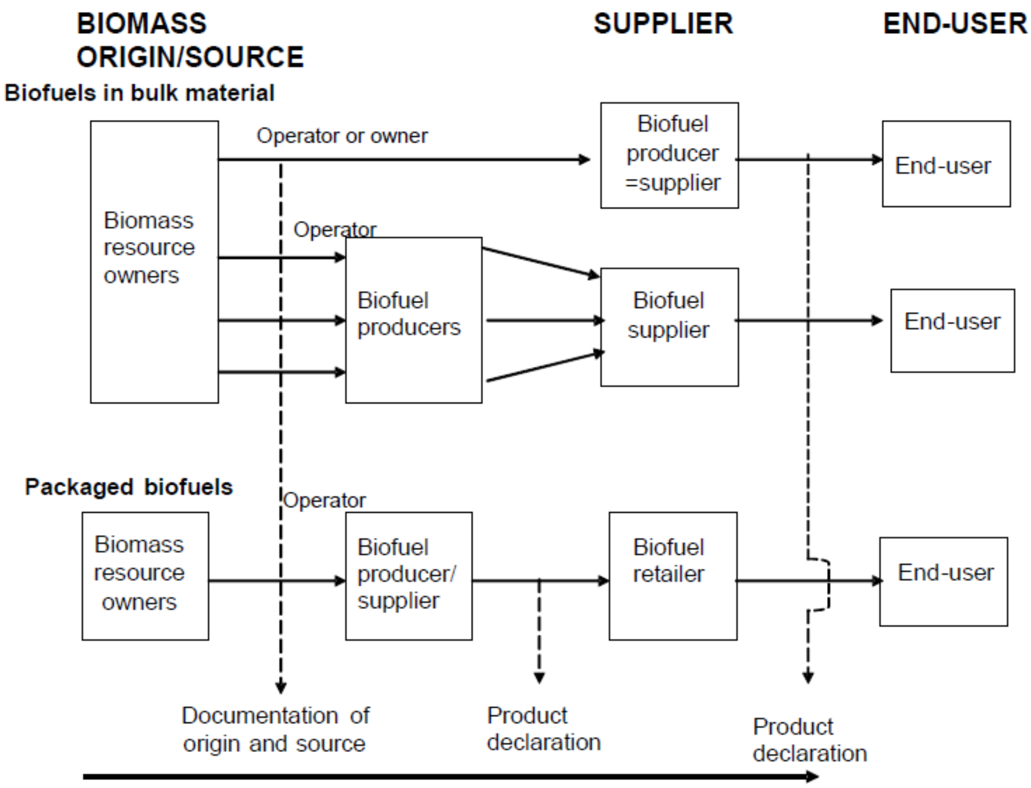

Figure 6: Examples of the documentation of origin and source and product declaration in different biofuel supply chains according to ISO ISO – Fuel quality assurance for solid biofuels

Source: ISO, 2010

However, the EN 15234-1:2011 (as well as ISO 9001:2000) provides an overview of the system requirements that should be included when designing OM systems. These systems are based on four so called 'pillars' (Fig. 7). The application of these pillars and their different measures depends on the problem and question asked (Langheinrich and Kaltschmitt, 2006):

- Quality Assurance (QA): Part of QM, focused on providing confidence that quality requirements will be fulfilled.
- Quality Control (QC): Part of QM, focused on fulfilling quality requirements.
- Quality Improvement (QI): Part of QM, focused on increasing the ability to fulfil quality requirements.

- Quality Planning (QP): Part of QM, focused on setting quality objectives and specifying necessary operational processes and resources to fulfill the quality objectives.

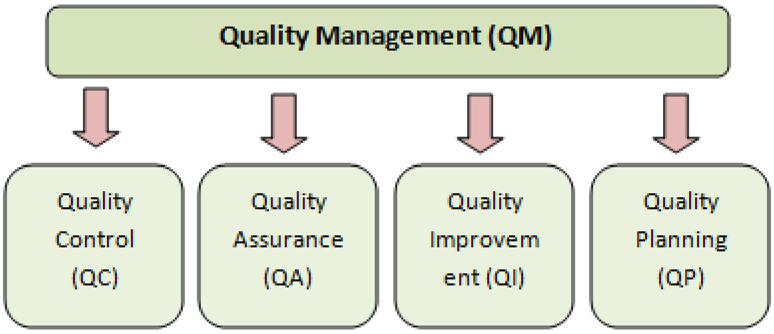

Figure 7: Main pillars of Quality Management according to ISO 9000:2000

Source: Adopted from Langheinrich and Kaltschmitt, 2006

Each of these quality tools has their own measures and approaches. The characteristic of the supply chain for solid biofuels places emphasis on QA and QC. QA measures should:

- be simple to operate,
- not cause undue bureaucracy, and
- offer savings in costs to both producers and users.

3.1.1 Quality assurance

QA activities include a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process (IPCC). These activities should provide confidence that the quality required by the customer is continuously fulfilled, which will in turn lead to customer satisfaction.

As with many other products, in the supply chain for solid biofuels, the customer in question is not necessarily the end-user. This is illustrated in Fig. 8 where the customer will often be the next organisation within the supply chain. Thus, the quality of the end product will be defined by each process step within the supply chain.

Further, Fig. 8 also demonstrates that the process of the identification and collection of the raw material will impact upon the production, packaging, labeling and storage of the solid biofuel. This in turn has a bearing on trade and delivery, as well as, the reception of the solid biofuel by the end user.

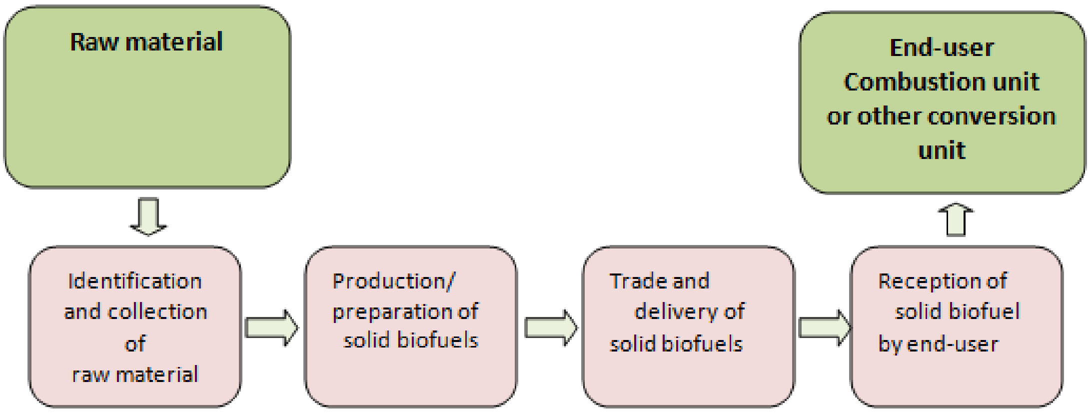

Figure 8: Solid biofuel supply chain

Source: Adopted from ISO, 2010

3.1.2 Quality control

QC is important to assess the properties of the fuel achieved, but it does not directly affect the quality of a product. In the context of solid biofuels, QC includes the selection and application of appropriate sampling and sample-reduction techniques, as well as test methods. However, the application of sample and test methods is expensive and should be applied carefully and not as a matter of routine. An appropriate QA system can reduce the frequency of testing and costs accordingly. Wherever possible, means should be sought to exempt parties from unnecessary procedures.

3.1.3 Product quality

For solid biofuels to be accepted in the marketplace, it is important that the requirements of the customers, in terms of fuel properties, are fulfilled whether or not those requirements follow a fuel-standard. The quality of solid biofuels can be defined by a number of key properties describing the suitability of the fuel for a specific application (see also section 2). The selection of these indicators can differ from case to case, depending on the foreseen application and the occurrence of natural variations in fuel characteristics under current production processes.

3.1.4 Quality of performance

The quality of performance is related to the following issues:

- The company's operation in terms of specific costs per unit of product;
- The company's recognition and fulfillment of the customer needs;
- The effectiveness and correctiveness of the work being carried out.

Thus, the term quality of performance refers to documentation, timing and logistical issues. Fig. 9 demonstrates the various aspects of demands on performances along the supply chain of solid biofuels.

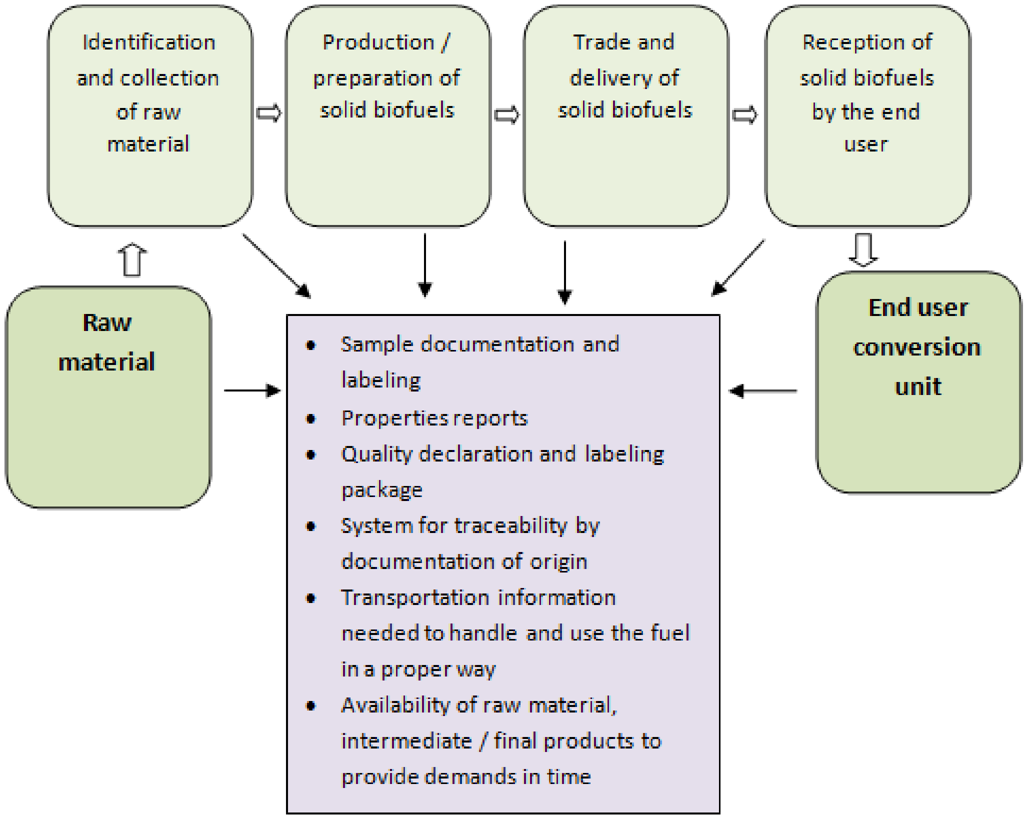

Figure 9: Aspects of demands on performances along the supply chain of solid biofuels

Source: Adopted from Langheinrich and Kaltschmitt, 2006

3.2 Quality assurance methodology

According to Langheinrich and Kaltschmitt (2006), the proposed methodology illustrated in Fig. 10 can be used by operators to design an appropriate QM system with emphasis on QA and QC for a specific part of the supply chain of solid biofuels. That means that the steps shown in Fig. 10 are applicable for each part of the supply chain. The methodology ensures—besides an efficient control of the processes considered—also the control over the overall supply chain by an integration of previous and subsequent process steps of other organisational units. Each implementation of these different steps of the methodology within a specific company should be documented in a site-specific manual. This manual can serve as an appropriate tool to illustrate to different parties that all the processes and their interaction are fully under control.

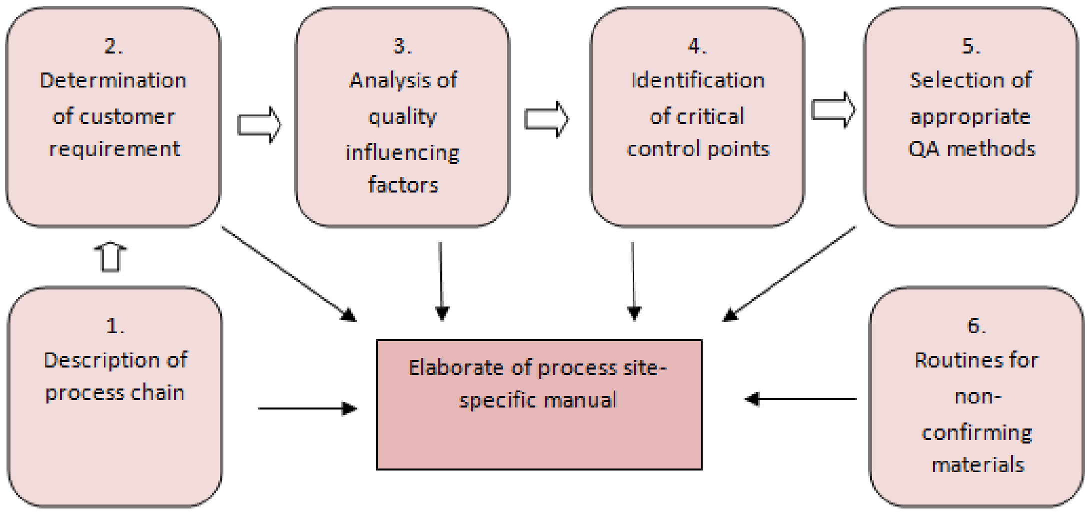

Figure 10: Methodology to apply and implement Quality Assurance

Source: Adopted from Langheinrich and Kaltschmitt, 2006

The documentation within the site-specific manual should fulfill minimum requirements related to the activities and processes of the part of the supply chain considered. Some documentation is mandatory while other documentation is voluntary.

Mandatory documentation on QA measures are (EN 15234-1:2011):

- documentation of origin (traceability of raw material),
- steps in the process chain, Critical Control Points (CCP), criteria and methods to ensure appropriate control at CCPs, non-conforming products (production requirements),
- description of transport, handling and storage,
- quality declaration/ labelling (final product specification)

3.3 Process chain

The first step in the production of a site-specific QA manual is to describe the production process. It is advisable to use a visual description or flow diagram of all process steps to be considered. As this description forms the basis for a more detailed assessment on where quality is/can be influenced, a sufficient level of detail must be included. Hence the description of the production process has vital importance for the subsequent drafting of the QA manual. It is important to gain the right balance between a detailed description, and one that does not fully appreciate the significance of certain steps within the context of QA. When describing the process chain it may be helpful to split the structure into distinct actions and also to certain persons or process owners (i.e., by an allocation of responsibilities).

3.4 Determination of customer requirements

The position of the process units(s) considered within the supply chain of the end-product is essential for QA because the customer requirements depend on previous and subsequent process steps, as shown in Fig. 11. In this regard the customer is not always the end-user of the final product. Furthermore, the product requirements may not necessarily be the requirements of a product-standard. However, the requirements of the next operator of the supply chain have to be fulfilled.

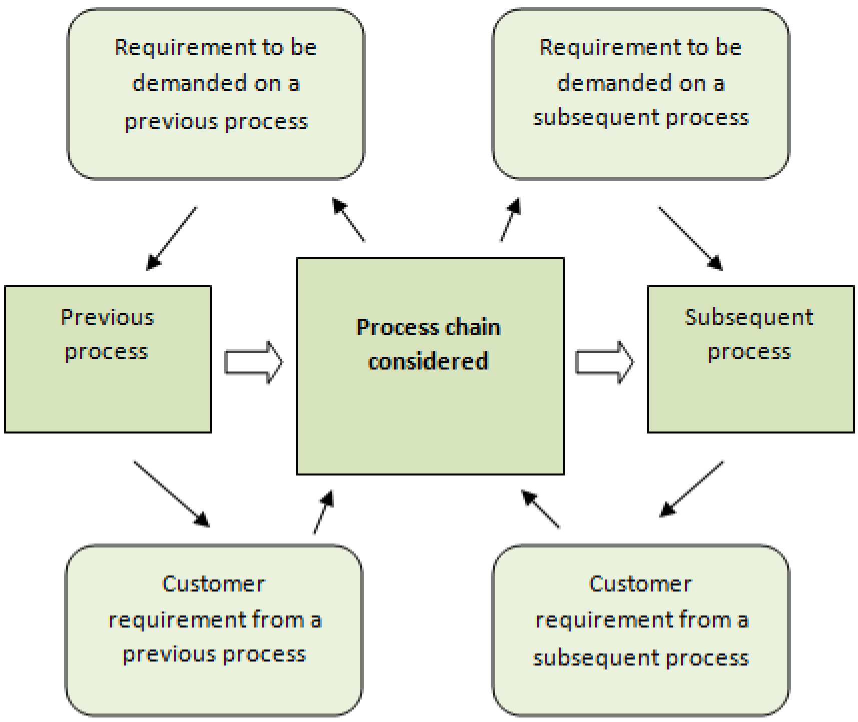

Figure 11: Determination of customer requirements

Source: Adopted from Langheinrich and Kaltschmitt, 2006

3.5 Quality influencing factors

According to Langheinrich and Kaltschmitt (2006), the following factors are involved in general in determining fuel quality and refer to the management of the company:

- Effectiveness of preliminary inspections of fuel sources—e.g., sawdust as raw material. This aspect is of importance to establish the suitability of the sources in general.

- Effectiveness of checking of incoming loads. This aspect ensures that the loads appear to be of one of the types already identified as suitable, and that the delivery notes are in harmony with the defined preconditions.

- Appropriateness of applied methods to handle, store and process materials. The necessary buildings and equipment have to be determined and designed to produce solid biofuels with properties according to the needs of the customers. Special attention should be given to the storage conditions.

- QC measures adopted. The frequency of testing should be managed so as to accomplish the appropriate level of control at the lowest level of cost.

- Company management and responsibility. The responsibility for the quality of the raw material or final product within the overall supply chain is transferred to the next operator according to the agreement of the different parties involved into this chain.

- Qualification and knowledge of staff. The staff needs to know about possible interactions between process-steps and the quality of the solid biofuel, environmental regulations, and the relevant regulations on occupational safety and health.

3.6 Selection of appropriate QA measures

In accordance with the results of previous steps of the methodology appropriate QA measures—i.e., measures giving confidence—have to be identified and applied. The following aspects should be taken into account:

- Allocation of responsibilities: The allocation of responsibilities should be accomplished in connection with the description of the process chain.

- Elaboration of work instructions: Working instructions and operation procedures could be in connection with the illustration of CCPs. Instructions should cover each work stage, e.g., transport, preparation processes, sampling and test procedures and maintenance.

- Proper documentation of processes and test results: A further pillar of confidence is the proper documentation to support, and report on, procedures operated throughout the supply chain, including test-results. The benefits of QM-systems cannot be delivered without proper documents; and those papers need careful preparation, and then trials and refinement, with reviews throughout the life of the production system.

- Training of staff: To ensure the demanded quality, the staff must be skilled; that is maintained by training. Therefore it is advisable to elaborate training guidelines for activities and workings with special regard to quality. The manual to be developed by the operator should prescribe the guidelines on how to train the personnel and how to keep their skills updated.

- System for complaint procedures: Information from complaints can be useful to determine quality-influencing factors. After specific complaints it often becomes clear what should be improved and where the objected quality is mainly influenced. A document for feedback can act to determine customers' satisfaction/ dissatisfaction.

- Customer satisfaction and maintenance of the QA-system: The organisation should determine the customer satisfaction. The success depends on each single unit of the supply chain. Therefore persons responsible for single units of the supply chain shall work in close cooperation with up-stream (subsequent processes) and down-stream process (previous processes) units to ensure a good information exchange as well as traceability and a transparent supply chain. The QA-system should be maintained and could be assessed by the information from the completed feedback documents.

- Preliminary inspection of raw material suppliers and formulating of acceptance criteria: It is advisable to inspect the raw material coming from every new entrepreneur before the first delivery to the plant. Appropriate procedures for the acceptation should be elaborated. As part of the pre-acceptance procedure, the acceptance criteria could be discussed with the customer of the intermediate/final product.

- Enforcement of QA meetings: It is an appropriate and effective measure to introduce a meeting with customers regularly evaluating their satisfaction. It can be understood as a preventive action to avoid (further) complaints. The QA manual to be developed by the operator should prescribe a minimum agenda for such a meeting to secure a good dialogue between operator and customer. A QA meeting can also be enforced within the company under the light of training.

- Failure Mode and Effect (FME) analysis: The Failure Mode and Effect analysis is an appropriate and valuable engineering quality method to demonstrate that the processes are under control. FME analysis helps to identify and counter weak points in the early conception phase of processes. It can be used to answer several questions about the operation and safety of a process where improvements can have substantial impacts on system performance. Utilising standard information and experience, the failure modes for each component are determined. For each failure mode, the effects are then determined and categorized as to severity.

3.7 Cost benefit analysis

The performance of a cost benefit analysis for solid biofuels should include factors such as production costs, environmental impacts and social benefits that are based on the overall process. The economic assessment can be described as follows:

- The direct economic impacts on the parties involved in the biofuel production processes, e.g. farmers, mills/refineries and biofuel industries;
- The assessment of the benefits and costs of the impacts of achieving the biofuels program targets.

The net cost (NC) that incorporates both internal and external factors as shown in Eq. (1) can be used to determine the true cost of solid biofuel production for the end consumer.

3.8 Solid biofuels supply chain

As mentioned above, the Biofuels Supply Chain (BSC) is a complex one, as it involves factors from various different fields. Typically, a biofuel production (chain) involves domains such as agriculture (energy crops, raw materials production), biofuel production (modification and adaptation of already existing plants or/and infrastructure development for new plants) and of course it involves the integrated distribution and trade network.

In the context of the integrated BSC, various problems emerge and call for solution. More specifically, in the strategic decision making, the identification of the best supply chain configuration includes (Dunnett et al., 2008):

- The selection of raw materials and the decision on domestic cultivation or import;
- The location of the conversion facility, its capacity and production technology;
- The partial or total satisfaction of the domestic demand from own production;
- The design and setup of the storage and distribution network.

In the operational level the decision making involves mainly planning problems, such as (Huang et al., 2010):

- The economic and performance measures that will evaluate the efficiency of the supply chain;
- The material flows in each stage.

The structure, the design and the operation of the BSC is the result of decision making that involves various considerations on economic, energy, environmental and in some cases social acceptability aspects. The added value from the biofuels sector for a country may be defined in terms of domestic raw materials and/or biofuel production, regional development, employment and other not strictly financial measures. Thus a country, depending on the availability of land and/or production facilities and knowhow, may decide to invest in any or all of these activities (Kaihara, 2003; Kim et al., 2003).

In more detail, the major activities-stages usually incorporated in BSC are the following (Fig. 12):

- Raw materials production (which is related to the land availability and suitability, soil's efficiency associated to different types of plants).
- Biofuels production (which refers to the transformation of raw materials into biofuels through various conversion processes).
- Blending (in the case that biofuels are provided to the end consumers mixed with conventional fuels).
- Biofuels' transportation; and finally
- Consumption in the distribution network.

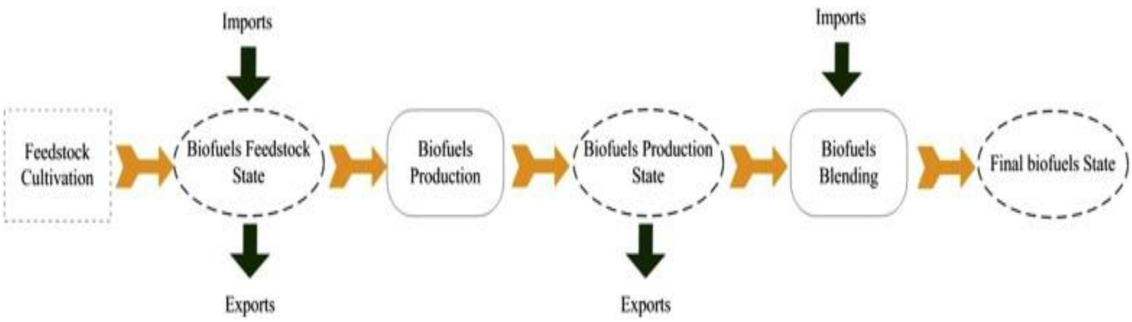

Figure 12: The biofuels' supply chain system

Source: Papapostolou et al., 2011

As it is illustrated in Fig. 12, in any stage of the supply chain there is a flexibility of importing the required quantities in case that they are not produced locally. As it is implied by the figure, the development of the domestic biofuels market, in a geographical area of a country, does not put any constraint on the origin of the raw materials and/or end products.

Accordingly, it is possible in any stage of the supply chain that sub-products are exported due to over adequacy or economic profitability. The decision point, i.e. in which stage of the supply chain an investor is going to step in, is a strategic decision for the development of biofuels' market and it is determined by multiple technical and financial parameters. The parameters that are determined in this decision point require firstly a techno-economic evaluation of the integrated biofuels production activity and a rational and structured appraisal method of different/alternative scenarios for the design and the operation of the supply chain (Meixell and Gargeya, 2005; Van Dyken et al., 2010).

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4. LIFE CYCLE ANALYSIS OF SOLID BIOFUELS IN WESTERN MACEDONIA

4.1 The region of Western Macedonia

The region of Western Macedonia is situated in north-western Greece, bordering with the regions of Central Macedonia (east), Thessaly (south), Epirus (west), and bounded to the north at the international borders of Greece with the Former Yugoslav Republic of Macedonia (FYROM) and Albania (Korce County) (Fig. 13).

Although it covers a total surface of 9451 km^2 (7.2% of country's total), it has a total population of 302,892 inhabitants (2.9% of the country's total), thus it is a low-density populated region (32 per km^2, as compared to the country's 79.7 relevant figure). This is mainly due to the mountainous nature of the region, as 82% of the total surface is mountainous or semi-mountainous areas. This is also reflected in the population distribution, as the major part of the population (56%) lives in rural areas. Capital of the region is Kozani with 47,451 inhabitants. Other main towns are Ptolemaida (32,775), Grevena (16,704), Florina (14,318) and Kastoria (13,959) (EL.STAT., 2011). As can be seen in Fig. 14, Western Macedonia includes four Prefectures (Florina, Grevena, Kastoria and Kozani). More detailed maps of these prefectures can be found in Appendix 3.

4.1.1 Economy, Environment, Education

The region is classified as a NUTS 2 region, with a per capita income (GDP) of 75% of the EU average (Eurostat, 2008). Western Macedonia mainly depends on the primary and the secondary sectors. The primary sector occupies 28% of the workforce and the secondary sector accounts for 35%. Currently, unemployment stands at 22.3%, the highest in Greece (EL.STAT., 2011), having been exacerbated by the economic crisis that the country is going through. Lignite extraction for power production has led to heavy industrialization and the region hosts the largest Greek electricity power production units, which contribute to 50% of the total electricity production of the country (EL.STAT., 2011).

This rapid and unplanned industrialization process has resulted in significant environmental problems and in the overreliance of the local economy on the energy sector. On the other hand, it has resulted in the concentration of considerable energy related expertise, which could prove advantageous in schemes that look to exploit energy sources. Further, the region benefits from the presence of the Institute for Solid Fuels Technology and Applications (ISFTA), the Technological Educational Institute of Western Macedonia (TEIWM), the University of Western Macedonia (UOWM), which provide much needed expertise and knowhow to the local and regional communities/industries and the country as a whole. Notable recent developments in the region include the completion of the Egnatia highway, which runs through northern Greece and connects Western Macedonia with every major urban center in the country and beyond, along the Turkey, Greece, Italy axis. Certainly, the future completion of the Turkey-Greece-Italy natural gas interconnection, which passes through Western Macedonia, presents a further opportunity for the region to establish itself as the major energy center in southeast Europe.

Figure 13: Location of Western Macedonia within Greece

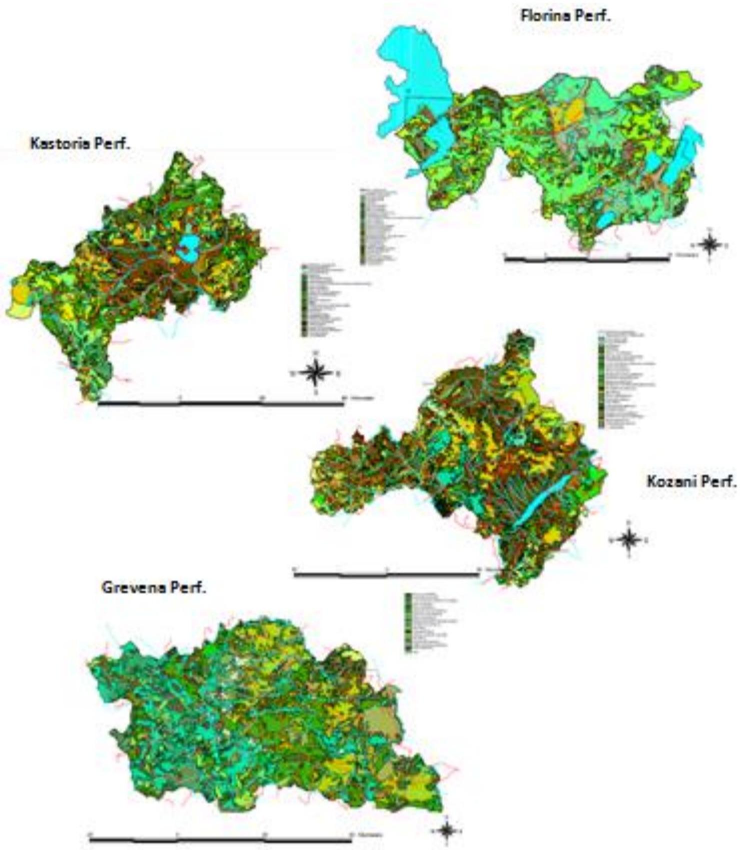

Figure 14: Surface map of the four Prefectures comprising the region of Western Macedonia (not on scale, but with geographic relation to each other's position)

Despite the presence of the institutes mentioned above, Western Macedonia lacks cutting edge technology facilities, as well as, the necessary expertise and knowledge to address the modern, major energy and environmental problems. The education level is low, with only 6% of the population having a university/ higher education diploma. Thus, the region of Western Macedonia is in a very disadvantaged position regarding the use and exploitation of scientific information regarding renewable energy sources and more specifically biomass/ biofuels utilization and production.

4.1.2 Land use and Land ownership

As mentioned above, most of the region of Western Macedonia is classified as mountainous or semi-mountainous (82% of the total). As a result, the percentage of the land area covered by woodland and upland pastures is quite large. However, as can be deduced from Table 10, there are significant differences between the Prefectures. Kozani for example has little forest cover, especially when compared with Grevena and Kastoria. On the other hand, most of the arable land is located in Lozani and Florina, however one has to bear in mind that some of this land is no longer available, due to the open cast mining for lignite extraction that takes place solely on those two prefectures

Table 10: Types of land use in Western Macedonia

Types of Land Use	Grevena		Florina		Kastoria		Kozani	
	Area (ha)	Share (%)	Area (ha)	Share (%)	Area (ha)	Share (%)	Area (ha)	Share (%)
Forestry and woodland	78,050.55	34.07	46,895	24.37	68,384.8	40	23,220	9.26
Shrubland	51,276.55	22.39	10,677	5.54	18,523.7	10.90	0	0
Pastures	41,793.4	18.24	55,137.1	28.65	38,679.2	22.70	132,410	52.79
Barren, Urban, Water	6298.5	2.75	17342	9.01	6592	3.90	22,530	8.98
Arable land	51,671	22.55	62,408	32,43	38,520.3	22.50	72,670	28.97
Total	**229,090**	**100.00**	**192,460.1**	**100**	**170,700**	**100**	**250.830**	**100**

Source: Gramelis et al., 2010

Table 11 provides information on the ownership of land in Western Macedonia. As one would expect (given the amount of available arable land), most private land is found in the prefecture of Kozani, while the least is found in the prefecture of Grevena. The largest chunks of land belong to the state and the local municipalities.

Table 11: Ownership of land (ha) in Western Macedonia

Owner	Forest	Shrubland	Pastures	Barren land	Arable land	Total	Share
FLORINA							
State	20,015	7016	13,952	1703	2986	45,672	50.09
Municipality	18,270	2970	6147	721	4501	32,609	35.76
Church	5		3			8	0.01
Joint ownership	6046	469	1669	343	613	9140	10.02
Private	2559	222	674	136	163	3754	4.12
Total	46,895	10,677	22,445	2903	8263	91,183	100
KASTORIA							
Owner	**Forest**	**Shrubland**	**Pastures**	**Barren land**	**Arable land**	**Total**	**Share**
State	55,326.8	14,374.1	34,726	1354.3	33,027.7	138,808.9	83.47
Municipality	12,200.2	3954.6	3795.2	813.9	5356.6	26,120.5	15.71
Church	222.2	110	108.0			440.2	0.26
Joint ownership	495.4	85	50.0	17.0	136	783.4	0.47
Private	140.2					140.2	0.09
Total	68,384.8	18,523.7	38,679.2	2185.2	38,520.3	166,293.2	100
GREVENA							
Owner	**Forest**	**Shrubland**	**Pastures**	**Barren land**	**Arable land**	**Total**	**Share**
State	48,899.55	37,691.55	32,465.4	4414.5	32,965	156,436	68.28
Municipality	16,490	10,695	7041	1256	16,019	51,501	22.48
Church	600	739	719	102	120	2280	0.99
Joint ownership	6788	624	1140	298	2256	12,106	5.28
Private	5273	527	428	228	311	6767	2.97
Total	78,050.55	51,276.55	41,793.4	6298.5	51,671	229,090	100
KOZANI							
Owner	**Forest**	**Shrubland**	**Pastures**	**Barren land**	**Arable land**	**Total**	**Share**
State	11,018	4502	4459	1943	725	22,647	50.57
Municipality	5006.4	1937	1130	120	392	8585.4	19.18
Church	70					70	0.17
Joint ownership	3421	372	2464.5	1685	862	7288	16.27
Private	3704.6	1547	887.5	49		6188	13.81
Total	**23,220**	**8358**	**8941**	**2280.5**	**1979**	**44,778.5**	**100**

Source: Gramelis et al., 2010

4.2 Biomass availability

As is well understood, biomass availability as a primary source for energy production is subject to significant fluctuations due to the weather conditions, the applicable agricultural practices in the area, the level of cultivation subsidies, the current EU and international regulations (e.g. Common Agricultural Policy, World Trade Organization) and the competitive uses for local biomass (e.g. for industrial forestry, paper, forage). Therefore, the estimation of the availability of the appropriate biomass for energy production, on an absolute constant base and under a strictly set composition and physical–chemical characteristics (e.g. fuel analysis, heating value, humidity, ash percentage and composition) is a very difficult (if not impossible) task. This holds true even if the research is limited to a particular geographic area (e.g., Western Macedonia). However, if a well structured and proven methodology is used, it is possible to make a safe, yearly averaged, estimation of the technically and economically available biomass quantities suitable for further energetic use (Boukis et al., 2009).

This issue is further compounded by the lack of reliable and systematic data collection of the energetic potential of the already available biomass in Greece, with the exception of the National Statistical Service of Greece (EL.STAT., 2011). Studies carried out by the Agricultural University of Athens, National / Regional energy offices and the Centre for Renewable Energy Sources are more general in nature. Moreover, it should be remarked that existing estimations concerning the available biomass potential in Greece present great differences among them. As an example, Karkania et al., (2012) have estimated the total biomass contribution, as primary energy, at 1 Mtoe/year, while Boukis et. al. (2009) are giving a figure of 0.4 Mtoe/year. In addition, it has to be mentioned that in the majority of the Greek Biomass studies studies there is no distinction between the theoretically available biomass and the technically and economically available biomass, which corresponds to the biomass that can be energetically exploited.

4.2.1 Forest biomass resources

It is hard to accurately quantify the amount of available forest residues for biofuels production not just in Western Macedonia, but to the country as a whole. Part of the reason has to do with the natural terrain and the existence of steep slopes, the lack of forest roads and the lack of mechanization in forest works. Moreover, the overall system of exploitation of forests by forest workers' cooperatives based on cost per unit (m^3) of raw wood produced do not encourage the removal of logging residues from the forest. Grammelis et al. (2010) have evaluated the forest residue availability for the region of Western Macedonia using the National Informational System for Energy (Table 12).

Table 12: Logging residues availability in Western Macedonia

Prefecture	Total logging quantity (tn/year)	Available Residue (wet tn/yr)	Available residue (dry tn/yr)	Energy (GJ/yr)
Broadleaves woods				
Kozani	13,152	1315	723	14,033
Grevena	10,428	1043	573	11,127
Florina	42,846	4285	2357	45,717
Kastoria	23,159	2316	1274	24,711
TOTAL	**89,586**	**8959**	**4927**	**95,588**
Coniferous woods				
Kozani	929	139	77	1,533
Grevena	3,032	455	250	5,003
Florina	129	19	11	213
Kastoria	6,324	949	522	10,435
TOTAL	**10,414**	**1,562**	**859**	**17,183**

4.2.2 Agricultural crop residues

Given the region's climatic characteristics residues that are abundant at a country level are totally absent from the area (e.g., cotton, olive and citrus trees). The most important cultivation is cereals (soft wheat, durum wheat, maize, barley) with 85.9% of the total available residue. Vineyard pruning (4.8%), apple tree pruning (3.2%), peach tree pruning (2.5%) and sugarbeat leaves (2%) are other important residues.

Cereal residues, such as wheat and oat, are mostly used for livestock feeding, bedding and mushroom production. Some quantities are also used for paper production, although exact data do not exist. The vast majority of the herbaceous residual biomass however is either burnt in the field or ploughed under to be used as an organic fertilizer. Small size tree pruning are burnt in open fires. Exploitation of agricultural residues for production of energy is not being practiced at the moment.

Since most residues do not currently have market prices, there have not been efforts in the establishment of mechanized systems for their collection or for an extended logistics chain. Wheat and corn are a notable exception; after harvesting of the crop, a linear pile of the straw from threshing of the combine harvester is created. Then, bales of straw of about 40kg each are made using a baler. The bales are loaded on tractor-pulled trailers and transported to neighboring livestock facilities. Larger branches from pruning are transported via trailers to the producer's household, while any excess production is sold in average market prices.

Table 13: Main crops and residue availability in Western Macedonia (total)

PRODUCT	Land (ha)	Quantity (wet tn)	Yield (wet tn/ha)	Total residue quantity (dry tn/year)	Residue Yield (dry tn/ha)	Available residue quantity (dry tn/year	Available residue (% of total)
Wheat soft	39,811	129,356	12.66	109,953	10.76	54,976	23.8
Wheat durum	60,576	145,740	8.94	123,879	7.58	61,939	26.9
Maize	22,343	233,834	42.42	95,872	17.4	57,523	24.9
Oat	210	443	3.82	297	2.56	148	0.1
Barley	21,038	69,406	12.52	47,196	8.5	23,598	10.2
Sugarbeat	1988	94,536	175.73	9454	17.58	4727	2.0
Tobacco	1697	2869	8.36	431	24.02	269	0.1
Sunflower	60	84	8.32	165	16.58	99	0.0
Pear tree	210	2009	53.46	402	10.7	321	0.1
Apricot tree	26	42	11.36	9	2.39	7	0.0
Cherry tree	198	636	14.42	318	7.19	254	0.1
Apple tree	2750	51,967	66	9354	11.89	7483	3.2
Peach tree	1048	30,367	297.74	7287	71.5	5830	2.5
Nectarine tree	181	4018	41.69	804	8.33	643	0.3
Almond tree	389	1065	15.38	2268	32.71	1814	0.8
Vines	2684	19,375	30.14	13,756	21.41	11,006	4.8
Totals	155,209	785,747		421,445		230637	

Source: Adopted from Grammelis et al. (2010)

4.3 Life cycle assessment

Life Cycle Assessment (LCA) is increasingly been adopted as an analytical tool that is able to capture complexity and inter-dependencies, thus providing a comprehensive and objective environmental balance, helpful to address sustainability of bioenergy chains. A recent, comprehensive and extensive literature review by Cherubini and Stromman (2011) pointed out how LCA of bioenergy systems can be helpful to address sustainability, but, at the same time, also showed how methodological assumptions might distort the results or render comparisons nearly impossible.

LCA studies should systematically and adequately address the environmental aspects of products/systems. The depth of the details and time frame of an LCA study may vary to a large extent, depending on the definition of goal and scope. The scope, assumptions, description of data quality, methodologies and output of LCA studies should be transparent. LCA methodology should be amenable to inclusion of new scientific findings and improvements in the state-of-the-art of the technology (Blengini et al., 2011). The strength of LCA is in its approach to study in a holistic manner the whole product/system and enables us to avoid the sub-optimization that may be the result of only a few processes being focused on. The results are also related for the use of a product, which allows comparisons between alternatives. LCA includes definition of goal and scope, inventory analysis, impact assessment and interpretation of results as shown in Fig. 15.

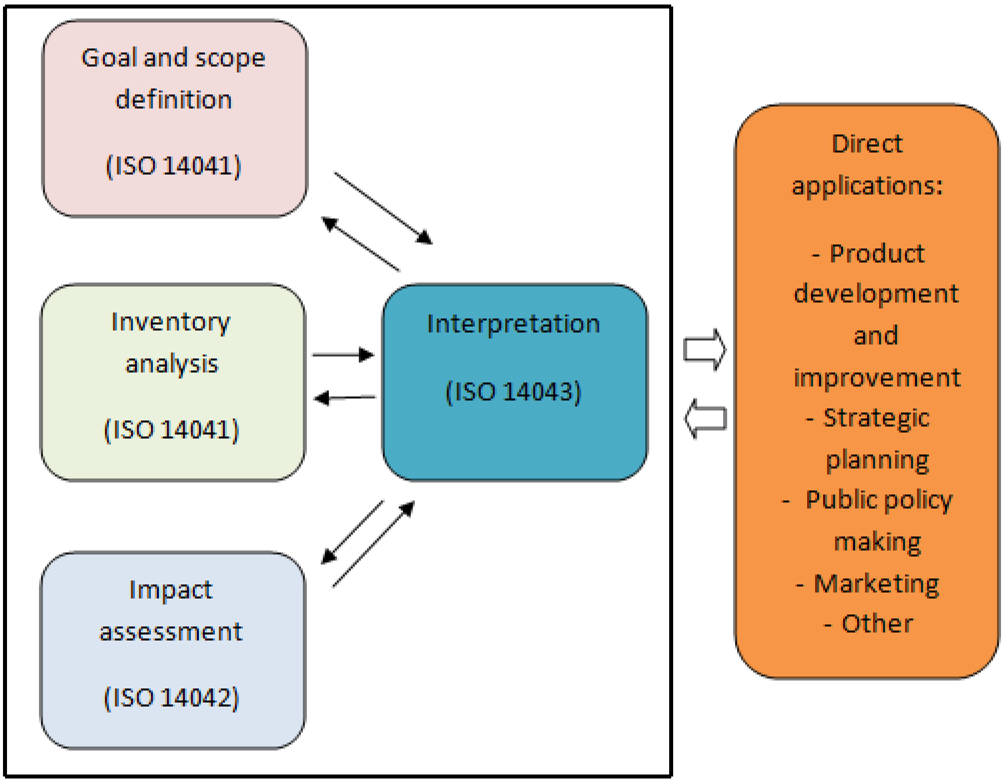

Figure 15: Life cycle assessment framework

Source: Adopted from Varun et al., 2009

An important application of LCA is net energy analysis. Net energy has been defined as the amount of energy that remains for consumer use after the energy costs of finding, producing, upgrading and delivering the energy have been paid (Wagner, 2007).

If a new technology consumed more energy than it produced so that it had a net energy output negative, it could not provide any useful contribution to energy supplies and should be dismissed as a net energy sink. Conversely, if a new energy technology could achieve a positive net energy output when energy is in short supply, then it should be adopted for use even if the economic evaluation of its prospects is found to be unfavourable (Mortimer, 1991.

Thus, LCA is an instrument to quantify all impacts of the entire energy supply chain, e.g. to obtain the cumulative energy demand (CED) for production of a power plant, its life cycle carbon emissions, etc. The whole facility is split up into components and subcomponents and all energy and material flows through these are examined (Sorensen, 1994).

4.3.1 Literature review of LCA on solid biofuels

LCA has been used by Jury et al. (2010) to evaluate the contribution to climate change of biogas production by monofermentation of cultivated crops. The result showed significantly lower emissions than the contribution of natural gas importation. Further, the effects on ecosystem quality and human health damages were evaluated.

Hartmann and Kaltsschmitt (1999) studied the environmental effects of electricity production from different biofuels by means of co-combustion with hard coal in existing coal fired power plants. They also compared electricity production from hard coal alone based on LCA. In their study they used straw and residual wood at a 10% blend with coal in an existing power plant in the southern part of Germany. The emissions of CO_2 equivalents for the provision of electricity from biomass were lower when compared to that from hard coal.

Rafaschieri et al. (1999)] used LCA to analyse the environmental impact of electric power production through an integrated gasification combined cycle (IGCC) fired by dedicated energy crops (poplar short rotation forestry (SRF). These results are compared with the alternative option of producing power by conventional fossil fueled power plants.

In order to define the required information concerning energetic aspects, experiences of co-digestion of energy crops and cow or pig manures have been conducted on different scales (Lehtomaki et al., 2007; Panichnumsin et al., 2010), in order to define the influence of operating parameters on methane yield and post-methanation potential.

The LCA methodology has also been applied by Hanegraaf et al., (1998) for the evaluation of the ecological and socio-economic sustainability of biomass crops: for different energy crops a net energy budget has been defined, with reference to avoided fossil energy, and it was possible to establish that, for large scale use, energy policies are required and policy instruments for financial incentives could be a preferred tool.

Blengini et al. (2011) used LCA to investigate bioenergy production from dedicated crops (maize, sorghum, triticale and miscanthus) and manure through anaerobic digestion and combined heat and power generation. Their LCA model was particularly focused on the end-of-life of digestate and site-specific data related to the impact of adopted energy conversion technologies. They concuded that bioenergy should not automatically be synonymous with sustainable energy, as the differences in terms of environmental performance can be quite large.

Fantozzi and Buratti (2010) used LCA to study about household heat from Short Rotation Coppice wood pellets combustion. The overall process, from field growth to ash disposal, was considered. The environmental analysis was carried out using the software programme (Simapro 7.0) and adopting the EcoIndicator 99 model for the evaluation of the global burden. They concluded that agricultural operations were responsible for most of the environmental impact.

Sebastian et al., (2011) used LCA to study two alternatives scenarios, namely biomass-only fired power plants, or cofiring in an existing coal power plant. They concluded that on the values and assumptions considered, a 29% net electric efficiency biomass-fired power plant would be required to achieve the same global GHG emissions decrease as biomass cofiring.

Puy et al. (2010) carried out an energy and environmental analysis of post-consumer wood and forest residues gasification in metropolitan areas aiming to determine the most critical stages of their life cycle. They examined three different scenarios and concluded that post-consumer wood from the collection from recycling points requires the 5% of the energy involved in the process, followed by the post-consumer wood from the collection of bulkywastes (7%), and, finally, forest residues that entail the 13% of the overall energy.

Zhong et al. (2010) analyzed the flash pyrolysis process, which is used for the production of bio fuels using biomass for power generation. A life-cycle assessment of flash pyrolysis of wood waste was conducted to study whether a flash pyrolysis plant set up locally would be environmentally friendly. They concluded that the process is environmentally friendly with little negative contribution to the environment.

4.4 LCA for solid biofuels in Western Macedonia

The present work concludes by presenting the results of the LCA study that was carried out for solid biofuels for the region of Western Macedonia. The study adopted a cradle to grave approach according to the standard ISO 14040 (2006). Forest residues have not been considered are currently difficult to exploit due to the steep slopes of the local terrain and the lack of forest roads and mechanization in forest works.

Thus, the present study considered only cereal residues due to their dominance in local agricultural practices that result (85.9% of total available agricultural residues). Arguably, the current management practices of open burning in the fields and/ or letting the residues rot (use as an organic fertilizer) underutilizes this recourse, further strengthening the arguments for their exploitation. The LCA model was created with the aid of the SimaPro 7 software application (2012).

4.4.1 LCA modelling and methodological assumptions

The system boundaries set are as follows:

- Agricultural processes (encompassing all direct and auxiliary agricultural activities ending with harvesting and transportation of the residues);
- Energy conversion to solid biofuels (pellets)

The Functional unit (FU) was 1MJ of net energy delivered and allocation of environmental impacts was based on energy content. Importantly the allocation method based on energy content is that the environmental impacts associated with 1MJ of electricity and 1MJ of heat are the same. Impact indicators were selected based on their representativeness of broadly recognized areas of environmental concern, according to the ISO recommendations (ISO 14040, 2006). Some of the indicators chosen are the following:

- GER (Gross Energy Requirement) expressing the primary energy resource consumption: direct + indirect + feedstock;
- NRE (Non Renewable Energy) as the non-renewable part of GER;
- GWP (Global Warming Potential – 100 years), as an indicator of the greenhouse effect;
- AP (Acidification Potential), as an indicator of acid rain phenomenon;
- EP (Eutrophication Potential), as an indicator of surface water eutrophication;
- POCP (Photochemical Ozone Creation Potential), as an indicator of photo-smog creation.

Characterisation factors for GWP, AP, EP and POCP are reported in the Method "CML, 2 baseline 2000" (SimaPro7, 2012). Among these, GWP of methane is assumed to be 23 kg CO_2 equiv./kg and nitrous oxide 296 kg CO_2 equiv./kg (Williams et al., 2006). Carbon uptake during plant growth and biogenic carbon dioxide emissions along the bioenergy chain were not accounted for as it was assumed that the biogenic carbon cycle is neutral (the amount of CO_2 absorbed during plant growth is equivalent to greenhouse emissions released during energy conversion and end-of-life of residues).

4.4.2 Agricultural processes

All agricultural processes were assumed to take place the region of Western Macedonia, therefore all factors depending on climate conditions or agricultural soil characteristics reflect the study area.Cereal cultivation covers the period end from the end of March to the beginning of September. With reference to the agricultural phase, inventory data are expressed per unit of cropland (ha) and subsequently implemented in the LCA model using the average biomass harvesting yields (t/ha, year). Data regarding the quantities of cereal residues available for biofuel production is presented in Table 13.

It was assumed that the field operations for cereal crops involve the shallow ploughing of the earth twice a year. The yearly diesel consumption was estimated at 30 lt/ha based on figures reported in the literature Sebastian et al., (2011). Oil consumption during the spreading of fertilizers, seeding, pesticide application, harvesting process and subsequent temporary storage was also taken into account. Irrigation was not taken into account as, at present, cereal fields in the area are not irrigated.

4.5 Results

Table 14 presents the air and water emissions that result from agricultural process, as calculated by the software. Table 15 shows the soil emissions.

Table 14: Air and water emissions from agricultural processes

Substance	Emitted	Maize (kg/ha/year)	Wheat durum (kg/ha/year)	Wheat soft (kg/ha/year)	Barley (kg/ha/year)
N_2O	Air	3.18	2.71	1.92	2.01
NH_3	Air	7.41	6.90	5.31	5.22
NO_x	Air	2.03	1.33	1.12	0.87
CH_4	Air	2.41	2.15	1.94	1.73
NO_3	Water	45.74	36.08	27.15	24.32
PO_4	Water	1.13	0.96	0.87	0.74

Table 14: Soil emissions

Substance	Maize (mg/ha/year)	Wheat durum (mg/ha/year)	Wheat soft (mg/ha/year)	Barley (mg/ha/year)
As	544	416	402	381
Cd	11,054	8523	8212	7617
Co	2942	2128	2466	1705
Cu	12,506	11,063	9418	7861
Cr	45,412	37,671	39,725	33,158
Mo	1252	1158	971	938
Hg	15	12	9	8
Pb	2127	1954	1743	1058
Ni	14,322	12,157	11,803	11,258
Se	1077	952	814	758
Zn	98,077	91,234	82,150	81,679

5. CONCLUSIONS

The EU has been one of the most vocal advocates of the need to adopt and implement global schemes that will help reduce GHG emissions, and a driving force behind the conception of the Kyoto Protocol. The Union's Renewable Energy Directive (RED) on the promotion of the use of energy from renewable sources is a powerful measure at the heart of European energy and climate policy. The RED is part of the European Commission's Climate and Energy Package from 2008, which lays out a strategy for the EU-27 MS to reduce their collective greenhouse gas emissions by at least 20% and to increase the share of renewable energy to 20% of total consumption by 2020. Bioenergy (biomass, biogas, bioliquids and biofuels) is expected to be the main contributor to the 2020 target, with an anticipated contribution of more than half of the 2020 renewable energy target as an average for the EU MS.

In this respect, the creation of a dynamic and sustainable Europe-wide market for biofuels that will create competition (and thus, help reduce prices) is imperative. The standardisation of some biofuel properties paves the way for the provision of information and tools that will eventually facilitate businesses transactions and thus, will help define the market rules for the different players. As an example, the standardisation of pellets was one of the driving forces that enabled the substantial market growth that was witnessed in the last decade since the pellet producer, the manufacturers of boilers and the end-users could benefit from the fact that the fuel properties are clearly defined.

Gaining the confidence and trust of customers within this market requires a demonstrable high level of quality for both biofuels and the combustion devices used. This is particularly important for the fuel quality, which can be influenced by various factors that are determined by the technology used throughout the overall supply chain, and even more by management. In general it is essential, that the demanded fuel quality—either it follows a standard or site specific customer needs—as well as other requirements of the customer are fulfilled. Thus, adequate controls should be ensured throughout the overall supply chain through the application of a Quality Management (QM) system with main focus on Quality Assurance (QA) and Quality Control (QC).

However, bioenergy chains are complex and inter-dependent systems made of industrial processes, which mostly depend on human decisions and control, and agri-forestry subsystems, which man can drive, but cannot control completely, thus complicating the overall picture. Bioenergy and sustainable energy should not therefore be used as synonymous in energy regulations, as, for instance, consequences like N_2O soil emissions, change in carbon pools and post-methanation from the storage of digested materials may offset greenhouse gas (GHG) savings. Similarly, public incentives might distort energy markets, or create unfair and inefficient competition against food and feed crops.

Biomass is equally suited for electricity generation, heating, cooling and fuels for transport, offering environmental benefits, but it can also additional environmental pressures. In fact a substantial increase in the use of biomass from agriculture, forestry and waste for producing energy could put further pressure on farmland and forest biodiversity, as well as on soil and water resources. Encouragingly, the development of renewable energy from biomass might also counteract other environmental policies and objectives, such as waste minimization or environmentally oriented farming.

For this reasons, Life Cycle Assessment (LCA) should be adopted as an analytical tool, as it is able to capture complexity and inter-dependencies. Thus, LCA can provide comprehensive and objective environmental balances that can help address the issue of the sustainability of bioenergy chains.

Western Macedonia mainly depends on the primary and the secondary sectors who occupy 28% and 38% of the workforce respectively. The region is badly affected by the economic crisis that has engulfed Greece with unemployment standing at 22.3%, the highest in the country. Lignite extraction for power production has led to a rapid and unplanned and industrialization process with significant environmental problems. Further, the local economy is vulnerable to abrupt structural changes due to its overreliance on the energy sector.

During the course of this study, it was revealed that within Greece, the region has considerable biomass resources. The exploitation of forest biomass resources currently presents a number of challenges due to the unhospitability of the natural terrain – with the existence of steep slopes - the lack of forest roads and the lack of mechanization in forest works. The vast majority of agricultural crop residues (mainly cereal residues, such as wheat and oats) is currently either burnt in the field or ploughed under to be used as an organic fertilizer. Less significant uses include livestock feeding, bedding and mushroom production. Thus, agricultural residues can be used for energy production by taking advantage of an underused resource. Such a step can help diversify the local economy and bring much needed income to a number of the remote rural communities that can be found dotting the area. However, this will require the establishment of mechanized systems for residue collection and an extended logistics chain.

The region benefits from the presence of the Institute for Solid Fuels Technology and Applications (ISFTA), the Technological Educational Institute of Western Macedonia (TEIWM) and the University of Western Macedonia (UOWM), which provide much needed expertise and knowhow to the local and regional communities/industries. These institutions can play a leading role in the exploitation of scientific information regarding renewable energy sources and more specifically biomass/ biofuels utilization and production.

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APPENDICES

APPENDIX 1: Indicative EU Supported Research, Development and Demonstration activities and Related Studies *(Source: European Biofuels Technology Platform, Available at: http://www.biofuelstp.eu/biofuelsmarkets.html)*

1. EBTP - European Biofuels Technology Platform

In 2009, 12.1 Mtoe (million tonnes of oil equivalent) of biofuels were consumed in the EU 27, accounting for 4 % of road transport fuels. Production needs to increase rapidly if Member States are to achieve the target of 5.75% by 2010, as set in the European Biofuels Directive (2003). In 2008, public concerns about the impact of some first generation biofuels caused several Member States to reduce these targets pending further research on sustainability issues and the wider availability of advanced biofuels. To help address these concerns and enable the EU27 to increase their market share of biofuels to 10% by 2020 (including a significant proportion of advanced biofuels) the European Biofuels Technolgy Platform (EBTP) aims to contribute to the development of cost-competitive world-class biofuels value chains and the creation of a healthy biofuels industry, and to accelerate the sustainable deployment of biofuels in the European Union, through a process of guidance, prioritisation and promotion of research, technology development and demonstration.

2. BIODIENET - Developing a network of actors to stimulate demand for locally produced biodiesel from used cooking oils (EIE/06/090/S12.448899)

BioDieNet aims to involve Energy Agencies across Europe in the local production and distribution of biodiesel from used cooking oils (UCO), stimulating demand for higher concentrations of this biofuel. The 17 partners in 10 regions will form a network to share expertise and experience and provide specific, practical information, education, dedicated tools and support to help set up and maintain projects which result in greater uptake of locally-produced biodiesel by public and private vehicle fleets as well as individual vehicle owners.

3. BIODIESEL CHAINS - Promoting favourable conditions to establish biodiesel market actions (EIE/05/113/S12.420022)

The Biodiesel Chains project aims to understand & promote favourable conditions for the establishment of biodiesel market chains in selected countries which have had limited developments to date. The work focuses on countries – Greece, Belgium, Poland, Cyprus, Romania & Bulgaria – that are making limited progress in creating markets to achieve European liquid biofuel policies & targets.

4. BIOFUEL MARKETPLACE - Web-based Biofuel Marketplace for Supporting the e-commerce of Biofuel Products and Technologies (EIE/05/022/S12.420009)

The Biofuel Marketplace project will act as an interactive web-based forum where Europe’s biofuel actors can promote their technologies, exchange ideas, sell and buy biofuel products, disseminate results of national, international and European research activities and raise the awareness both of the public and the professional community. The on-line supply and demand information system is expected to encourage the further exploitation of the EU biofuels potential.

5. BIOGASMAX - Biogas Market Expansion to 2020 (FP6 - 019795)

The overall goal of this project is to reduce dependency on oil, reduce greenhouse gases and direct emissions through increased and more efficient production, distribution and use of biogas in the transport sector generated from a wide variety of feedstock available in urban areas and regions in Europe. The project adopts the well-to-wheel approach to identify the potential for efficiency gains and cost optimisation to ensure market expansion. It aims to prove the technical reliability, cost-effectiveness, environmental and societal benefits of biogas fuels and perform large-scale demonstrations to optimise industrial processes, experiment and benchmark new and near-to market techniques and expand biogas fleets as well as to identify and assess ways to remove technical, operational, organisational/institutional barriers, which can inhibit or prevent alternative motor fuels and energy efficient vehicles from entering the market.

6. BIOMOTION Biofuels in Motion (IEE)

Aims to increase the use, knowledge and acceptance of biofuels. An international cluster of relevant actors and seven biofuel information centres will be established. A number of highly visible examples, or "beacons", will be used to demonstrate the use of various raw materials for the production of different biofuels on a commercial scale. The BioMotion Tour, with vehicles powered by several types of biofuels, will show the advantages of using biofules. The project should encourage the development of biofuel supply chains and highlight market opportunities, particularly in rural areas. In addition to professional advice, the project contains specific motivation and PR actions aimed at particular target groups in accordance with the motto: Bio fuels in Motion by Information and Motivation.

7. BIOPROM Bioenergy-Promotion - Overcoming the non-technical barriers of project-implementation for bioenergy in condensed urban environments (Altener EIE-04-38585)

This project aimed to overcome non-technical constraints of the realisation of bio-energy projects in densely populated urban areas and to bring bioenergy projects on their way by establishing a network of actors and stakeholders of the bioenergy sector in five European regions. Biogas, biofuel, wood chip and wood pellet projects are considered within the project. The five different EU regions involved in this project lie in France, Slovenia, Austria and Germany.

8. BOOSTING BIO - Boosting Bioenergy in Europe (Altener EIE-04-38592)

The main aim of this project was to boost bioenergy use in Europe through targeted actions in 2005 and 2006, developing a vision for bioenergy in 7 EU Member States and consultation with policy makers and private companies. The vision for bioenergy will be worked out with a strategy to develop bioenergy further, based on a market analysis where financial instruments will be taken into account. This strategy will be integrated with views from national decision makers and industries in order to evaluate it.

9. CAB-CEP (BIOFUELS CITIES) - Biofuel Cities European Partnership (FP6 - 020085)

The Biofuel Cities project develops and maintains the 'Biofuel Cities European Partnership' in order to demonstrate the broadscale use of new and innovative biofuel technologies. Biofuel Cities covers the complete chain from feedstock to biofuels production, distribution and utilisation in vehicle fleets. The 'Biofuel Cities European Partnership' is set up with the aim to become a permanent institution.

10. CARBON LABELLING - Carbon Efficiency Labelling & Bio-Blending for Optimising benefits of Biodiesel & Additive Use (EIE/06/015/S12.442654)

The Carbon Labelling project implements several labelling measures in Europe which focus on transportation products and services with low CO2 emissions. The project promotes biodiesel, fuel efficiency improvements and ‘low carbon’ freight services. This first European carbon labelling initiative helps meeting greenhouse gas reduction targets of the European Union, reduces petroleum dependence and helps to combat climate change.

11. ELOBIO Effective and Low-disturbing Biofuels (EIE-07-139-S12.467616)

This project develops low-disturbing policy options, enhancing biofuels but minimising the impacts on e.g. food and feed markets, and markets of biomass for power and heat. The project consists of a review of current experiences with biofuels and other RE policies and their impacts on other markets, iterative stakeholder-supported development of low-disturbing biofuels policies, model-supported assessment of these policies' impacts on food

& feed and lignocellulosic markets, and finally an assessment of the selected optimal policies on biofuels costs and potentials.

12. HyLights - Hydrogen for Transport in Europe (FP6 - 019990)

This is a coordination action that aims to accelerate the commercialisation of hydrogen and fuel cells in the field of transport in Europe on the basis that hydrogen enables the transport sector to phase in renewable energies on the path to cleaner mobility. HyLights will draw on a network of relevant experts. For this purpose an European Partnership for Hydrogen in Transport (EPHT) will be established to extend the reach of the European Hydrogen and Fuel Cells Platform (HFP).

13. MADEGASCAR - Market development for gas driven cars (IEE)

MADEGASCAR (Market development for gas driven cars) is a project operating from September 2007 to January 2010, funded by the IEE programme. The project aims at developing the market for gas driven vehicles – natural gas and biomethane fuelled vehicles – with the overall goal to increase the number of energy efficient and alternative fuelled vehicles in European countries. The project will address existing barriers by creating more acceptance on the consumer side, educating fleet owners as well as car dealers, incentive programmes and by awareness raising and information activities. On the other side activities for a better supply infrastructure (fuel stations) and market structure, including the integration of biogas, will be carried out.

14. PREMIA - R&D, demonstration and incentive programmes effectiveness to facilitate and secure market introduction of alternative motor fuels (FP6 - 503081)

This a Specific Support Action that aims to assess the effectiveness of measures to support the market introduction of alternative motor fuels, taking into account the national context of member states. Three categories of fuels are envisaged: bio fuels, natural gas and hydrogen. Certain alternative fuels are closer to market maturity than others. Bio fuels could achieve market maturity rather soon (estimated up to 2010), while hydrogen is much further away (estimated up to 2020). Although a general European approach is most obvious, country-specific conditions and constraints may require different approaches in different countries. The strategy to introduce alternative motor fuels is best adapted to the specific country legislation, the available resources (e.g. land for bio fuels), supply opportunities and available energy sources and available infrastructure - so especially for the new member Countries a specific approach may be needed.

15. PRO-BIODIESEL Overcoming Non-Technological Barriers For Full-Scale Use of Biodiesel In Europe (Altener EIE-05-111)

The general objective of this project was to promote biodiesel as a competitive and commercial product in the European fuel market, using the broadest range of raw materials both from North and South-Europe and considering all the agents involved. One of the aims was to successfully put in the market 35,000 t/year of biodiesel, which represents an increases of 2.3% biodiesel on the production of EU-25 in 2003.

16. REFUEL Renewable Fuels for a Sustainable Europe (Altener EIE-05-042)

The object of this project is to develop a roadmap for biofuels to reach a target market penetration in 2030 in an effective way. It expects to deliver a meaningful road map that is consistent with EU policies and which has been discussed and agreed by a wide range of stakeholders resulting in a biofuels scenario consistent with a target market penetration in 2030 together with a design of the required supply chain and market structure, the assessment of costs and potentials and the short and long term barriers to implementation.

17. VIEWLS: Clear Views on Clean Fuels - Data, Potentials, Scenarios, Markets and Trade of Biofuels (FP5 - NNE5 – 00619)

The aim of this project was to bring together information and future perspectives concerning the use of biofuels for transportation. It aimed to assist policy makers, NGO's and industrial decision makers in the selection of optimal pathways for the development and market introduction of biofuels in Europe. The project has now ended and many of the features have been transferred to the coordination project Biofuel Cities

18. ZERO REGIO - Lombardia & Rhein-Main towards Zero Emission: Development & Demonstration of Infrastructure Systems for Alternative Motor Fuels (Bio-fuels and Hydrogen) (FP6 - 503190)

This project has the overall objective of developing low-emission transport systems for European cities. The specific objectives of the project are to demonstrate the use of hydrogen as an alternative motor fuel, produced as primary or waste stream in a chemical plant or via on-site production facilities; development of infrastructure systems for alternative motor fuels (bio-fuels & hydrogen) and integrating them in conventional refuelling stations. This will include demonstration of 700 bar refuelling technology for hydrogen blends of bio-fuels in fuel flexible vehicles, demonstration of alternative fuels via. automobile-fleet field tests at two different urban locations in the EU, Rhein-Main, Germany and Lombardia, Italy and demonstrating ways and prospects for faster penetration of low-emission alternative motor fuels in the market at short and medium term.

19. BIO2NORM - Pre-normative research on solid biofuels for improved European standards ((ENK6-CT-2001-00556)

BIONORM project aimed to develop the market for solid biofuels in particular, as an alternative to fossil fuels, thus meeting the objectives set forth by the European Commission. Setting appropriate quality standards is regarded as the first step towards wider market applicability for biofuels. These new standards have largely been based on extensive sampling work and the testing of physical-mechanical fuel characteristics. German-based project partner, Institute for Energy and Environment concentrated on the standardisation of solid biofuel properties. Researchers undertook the creation of a Quality Management system, which would include quality assurance and quality control components. One of the first tasks was a review of existing quality management processes among industrial parties active in the solid biofuel arena. The review spanned six different countries and product categories included used wood, straw bales and pelletised animal feed. Based on the drawn conclusions, practical applications and termed field-trials of a novel Quality Assurance system were initiated. These field-trials, which included companies of different activity profiles, demonstrated the need for a unified quality guideline methodology applicable to all types of users. As part of a broader framework, these outcomes could signify the first steps towards new market opportunities for solid biofuels across the EU and beyond.

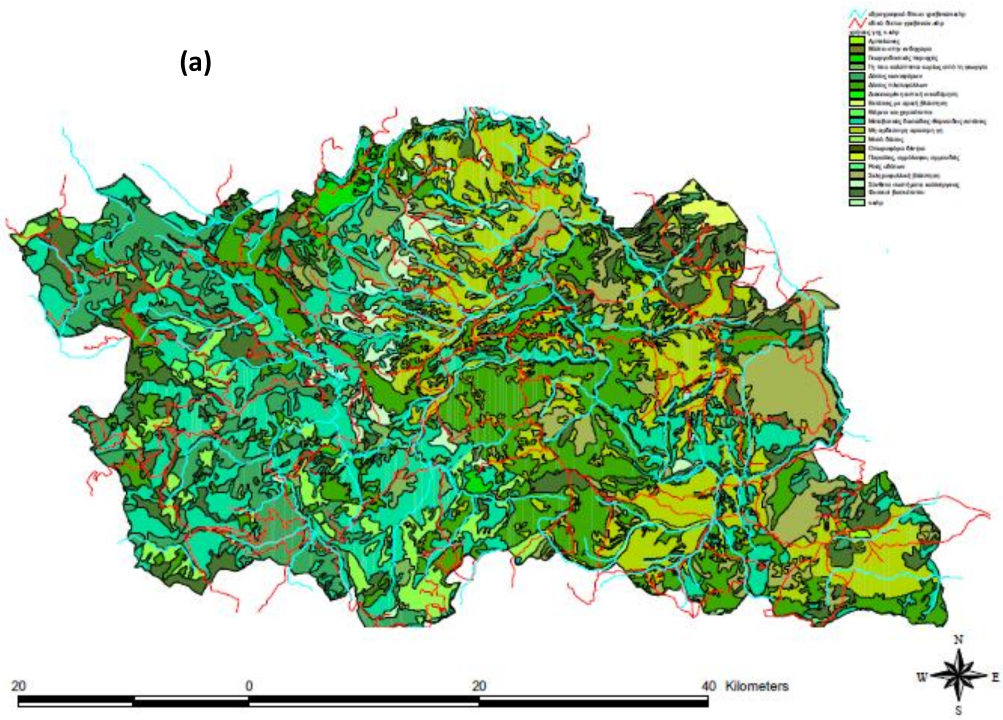
APPENDIX 2: National Standardisation Bodies *(Source: Comitato Termotecnico Italiano Energia E Ambiente)*

Country	Code	Name	Web site
AUSTRIA	ASI - ON	Austrian Standards Institute - Österreichisches Normungsinstitut	www.as-institute.at
BELGIUM	NBN	Bureau de Normalisation/Bureau voor Normalisatie	www.nbn.be
BULGARIA	BDS	Bulgarian institute for standardisation	www.bds-bg.org
CROATIA	HZN	Croatian Standards Institute	www.hzn.hr
CYPRUS	CYS	Cyprus organisation for standardisation	www.cys.org.cy
CZECH REPUBLIC	UNMZ	Czech Office for Standards, Metrology and Testing	www.unmz.cz
DENMARK	DS	Dansk Standard	www.ds.dk
ESTONIA	EVS	Estonian centre for standardisation	www.evs.ee
FINLAND	SFS	Suomen standardisoimisliitto r.y	www.sfs.fi
FRANCE	AFNOR	Association française de normalisation	www.afnor.org
GERMANY	DIN	Deutsches Institute für Normung e.V.	www.din.de
GREECE	ELOT	Hellenik Organization for Standarization	www.elot.gr
HUNGARY	MSZT	Hungarian Standards Institution	www.mszt.hu
ICELAND	IST	Icelandic Standards	www.stadlar.is
IRELAND	NSAI	National Standards Authority of Ireland	www.nsai.ie
ITALY	UNI	Ente Nazionale Italiano di Unificazione	www.uni.com
LATVIA	LVS	Latvian Standards Ltd	www.lvs.lv
LITHUANIA	LST	Lithuanian Standards Board	www.lsd.lt
LUXEMBOURG	ILNAS	Institut Luxembourgeois de la normalisation, de l'accreditation, de la sécurité et qualité des produits et services	www.ilnas.lu
MALTA	MSA	Malta Standards Authority	www.msa.org.mt
THE NETHERLANDS	NEN	Nederlands Normalisatie-instituut	www.nen.nl
NORWAY	SN	Standard Norway	www.standard.no
POLAND	PKN	Polish Committee for Standarization	www.pkn.pl
PORTUGAL	IPQ	Instituto Português da Qualidade	www.ipq.pt
ROMANIA	ASRO	Romanian Standards Association	www.asro.ro
SLOVAKIA	SUTN	Slovak Standards Institute	www.sutn.sk
SLOVENIA	SIST	Slovenian Institute for Standarization	www.sist.si
SPAIN	AENOR	Asociación Española de Normalización y Certificación	www.aenor.es

Country	Code	Name	Web site
SWEDEN	SIS	Swedish Standards Institute	www.sis.se
SWITZERLAND	SNV	Schweizerische Normen-Vereinigung	www.snv.ch
UNITED KINGDOM	BSI	British Standards Institution	www.bsigroup.com
Country	Code	Name	Web site
ALBANIA	DPS	General Directorate of Standardisation	www.dps.gov.al
ARMENIA	SARM	National Institute of Standards	www.sarm.am
AZERBAIJAN	SCSMP	State Agency on Standardisation, Metrology and Patent of Azerbaijan Republic	www.azstand.gov.az
BELARUS	BELST	State Committee for Standardisation of the Republic of Belarus	www.gosstandart.gov.by
BOSNIA HERZEGOVINA	BAS	Institute for Standardisation of Bosnia and Herzegovina	www.bas.gov.ba
EGYPT	EOS	Egyptian Organization for Standardisation & Quality	www.eos.org.eg
REPUBLIC OF MACEDONIA	ISRM	Standardisation Institute of the Republic of Macedonia	www.isrm.gov.mk
GEORGIA	GEOSTM	Georgian National Agency for Standards, Technical Regulations and Metrology	www.gnims.caucasus.net
ISRAEL	SII	Standards Institution of Israel	www.sii.org.il
JORDAN	JSMO	Jordan Standards and Metrology Organization	www.jsmo.gov.jo
LEBANON	LIBNOR	Lebanese Standards Institution	www.libnor.org
LIBYA	LNCSM	Libyan National Centre for Standardisation and Metrology	www.lncsm.org.ly
REPUBLIC OF MOLDOVA	INSM	National Institute of Standardisation and Metrology	www.standard.md
MONTENEGRO	ISME	Institute for Standardisation of Montenegro	www.isme.me
MOROCCO	SNIMA	Service de Normalisation Industrielle Marocaine	www.snima.ma
SERBIA	ISS	Institute for Standardisation of Serbia	www.iss.rs
TUNISIA	INNORPI	National Institute for Standardisation and Industrial Property	www.innorpi.tn/en
TURKEY	TSE	Turkish Standards Institution	www.tse.org.tr
UKRAINE	DSSU	State Committee of Ukraine for Technical Regulation and Consumer Policy	www.dssu.gov.ua

APPENDIX 3: Surface map of (a) Grevena Prefecture, (b) Florina Prefecture (c) Kastoria Prefecture, (d) Kozani Prefecture *(Source: Gramelis et .al., 2010)*

(a)



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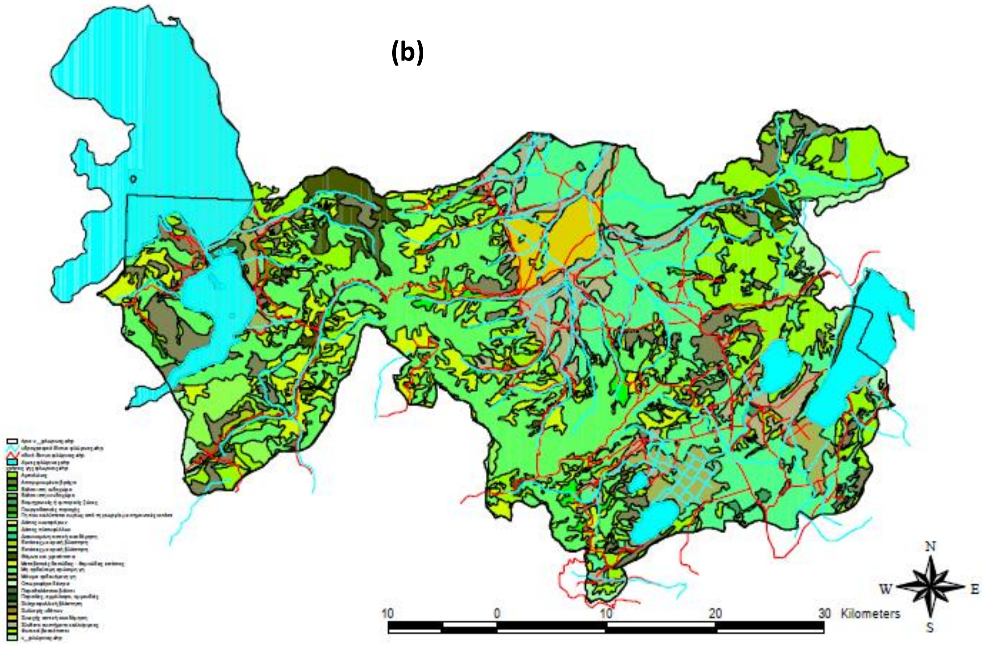
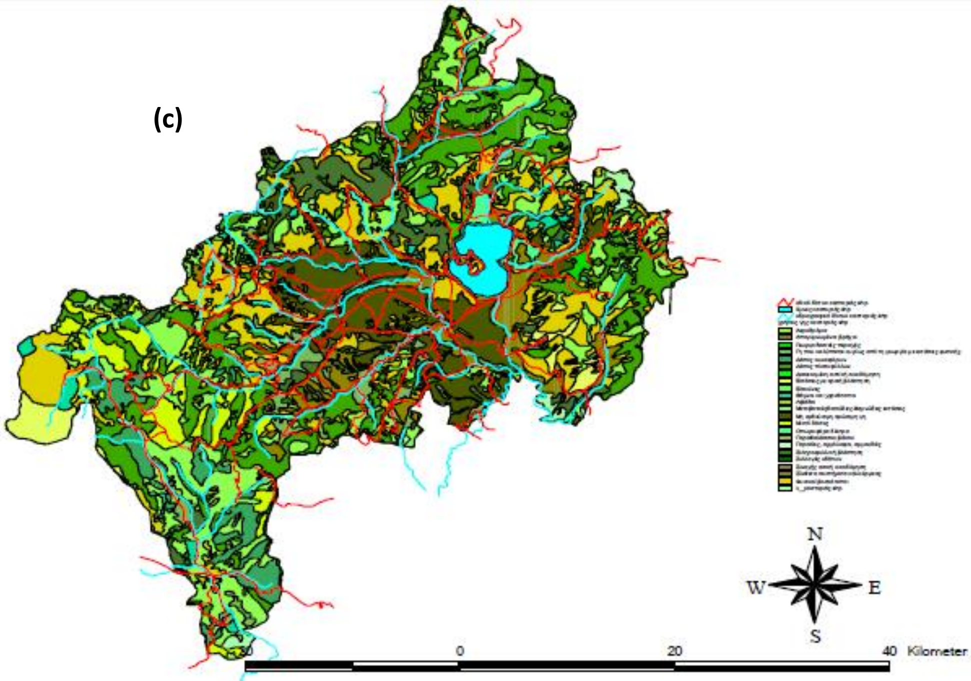


(c)



(d)