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sustainable biomass energy

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Sustainability implementation and certification of solid bioenergy pathways

Case studies of the EU H2020 project SecureChain

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Glossary

Allocation	Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems. (ISO 14040/44:2006)
Allocation factor	Allocation factors are used for partitioning of a multifunctional system into several single-functional processes by economic value or energy basis. (Guinée et al., 2009)
Background system (LCA)	Background processes should represent the average market consumption mix. (European Commission, 2010a)
Bioenergy carriers	Include wood pellets, wood chips, wood logs, biogas, biomethane, bioethanol and biodiesel
Biomass feedstock	Feedstock from which bioenergy carriers are developed, such as forest wood, agricultural residues, wood industry residues, manure, co-digestion feedstocks, food and beverage industry residues, and used cooking oil
Biomass heating plant	Plant which produces heat from biomass energy carriers
Foreground system (LCA)	The foreground system should aim at using primary data from the producer / operator and secondary data from suppliers and downstream users/customers. (European Commission, 2010b)
FTE Full-time equivalent	Full-time means the minimum hours required by the relevant national provisions governing contracts of employment. If the national provisions do not indicate the number of hours, then 1 800 hours are taken to be the minimum annual working hours: equivalent to 225 working days of eight hours each.
Functional unit	Quantified performance of a product system for use as a reference unit. (ISO 14040/44:2006)
GHG	Green-house gas emissions
Global Warming Potential (GWP)	A globally-recognised model (the Bern model) developed by the Intergovernmental Panel on Climate Change (IPCC) that calculates the radiative forcing of all greenhouse gases.
Intergovernmental Panel on Climate Change (IPCC)	The Intergovernmental Panel on Climate Change (IPCC) is the international body for assessing the science related to climate change. The IPCC was set up in 1988 by the World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP) to provide policymakers with regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation. www.ipcc.ch
LCA Life Cycle Assessment	Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle. (ISO 14040/44:2006)

LCI Life Cycle Inventory	Phase of Life Cycle Assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle. (ISO 14040/44:2006)
LCIA Life Cycle Impact Assessment	Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product. (ISO 14040/44:2006)
Life Cycle	A unit operations view of consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal. This includes all materials and energy input as well as waste generated to air, land and water. (ISO 14040/44:2006)
Life Cycle Assessment (LCA)	LCA addresses the environmental aspects and potential environmental impacts (e.g. use of resources and the environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (i.e. cradle-to-grave). (ISO, 2006a)
Life Cycle Interpretation	Phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations. (ISO 14040/44:2006)
LULUCF	Land Use, Land Use Change and Forestry Emissions
Pilot company	A company which submitted a pilot project to SecureChain and conducts the pilot project within SecureChain.
Pilot project	A project which is supported with the innovation voucher from SecureChain and which are assessed regarding their sustainability performance (LCA or KPI)
Regional Lead Partner (RLP)	Partner of SecureChain who is in charge of the pilot project in a European model region.
SME	Small and medium sized enterprise
SRC	Short rotation coppice

1 Executive Summary

Sustainable development means 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (Brundtland, 1987). A long list of sustainability criteria has been developed by scientists during the last decades, but exceedingly few criteria can be assessed in a quantitative way.

The WP4 objective of the SecureChain project was to select suitable sustainability criteria to check and proof sustainability of pilot cases in six model regions in Europe. Pilot cases were accompanied by the project with training and coaching activities that equipped SMEs with specific technical-logistical knowhow to support their broader market uptake. The ambition of the assessment was to show how SMEs can proof and improve their sustainability. The assessment was carried out by means of Life Cycle Assessment (LCA). This report presents the sustainability assessment, their implementation in pilot projects, and related sustainability certification practices which were supported through the SecureChain project.

Sustainability has three dimensions: environmental, social and economic. The environmental dimension was assessed by means of a quantification of life cycle GHG emissions of the bioenergy system. The 'GHG indicator' was used to measure the reduction of GHG emissions of a bio-based fuel chain in comparison with a fossil-based fuel chain in a quantitative way. If suitable LCA data was not available to calculate the GHG indicator, default values of Giuntoli et al. (2015) were considered instead. The quantitative indicator 'regional job creation potential' was considered to quantify social impacts. The indicator quantifies the potential of green jobs created by bioenergy systems. Results can be compared to jobs in fossil-based energy systems. The difference is that a large share of the workforce (e.g. for acquisition of feedstock, processing of energy carriers) stays within the region in case of bioenergy, whereas in case of fossil energy systems those steps of the supply chain most often occur in another economic area (even on other continents).

Besides lifecycle GHG emissions and job creation potential, several qualitative sustainability criteria were assessed. They were selected based on their relevance for the case studies. From an environmental point of view, the harvest yields of wood resources, more concretely the ratio of annual increments and annual fellings of wood on forest land available for wood supply in a country was considered. In case of energy crops, soil and water quality, water use and efficiency as well as land use change are important indicators which should not be neglected. The indicator air quality is of major relevance for bioenergy because of the release of particulate matter or air emissions due to incomplete combustion processes. Biodiversity is an important concern, if major interference is undertaken in forests and other woodland for the purpose of bioenergy. Regarding the social pillar of sustainability, market acceptance was selected besides the workforce (job creation potential) as a relevant indicator. From an economic point of view, energy efficiency is an important indicator, but data for an assessment was not always available. Therefore this indicator was only considered in a qualitative way. Furthermore, energy diversity is another important aspect on regional scale. If energy diversity can be increased by solid biomass, it leads to more energy security and consequently energy independency.

SecureChain's pilot projects lead to additional mobilised biomass mainly from regional sources that yielded a total volume of mind. 77,000 tons. Sustainability of the pilot projects was assessed first of all by means of LCA to detect environmental hot spots and to calculate estimations of lifecycle GHG emissions along the supply chain from primary data. The LCA helped to understand specific research questions and their effects on the environmental performance, in this case on the GHG emission performance. Primary data obtained from pilot projects were of sufficient quality. Good cooperation and communication with SMEs during data collection enhanced the quality of the study. Besides the LCA, a sustainability assessment was carried out with respect to environmental impacts other than Climate Change, furthermore considering social and economic impacts. All pilot projects emitted fewer GHG emissions than equivalent fossil systems. A total saving effect of mind. 42,000 tons CO_2-eq. compared to fossil energy was quantified (on average 50,000 tons CO_2-eq.). Relevant sustainability indicators were addressed for all pilot projects in the most objective way, which means that both positive but also negative aspects on the performance were highlighted in relation to each pilot case. A regional job creation potential of approx. 58 FTE was achieved by the pilot projects.

Certification was identified as one important tool for market mobilisation. The training seminars aimed at knowledge transfer about quality aspects of solid biofuels to regional practitioners and experts. The seminars focussed on quality assurance via certification along the supply chain. The main interest of the stakeholders was the combination of pellet quality assurance with sustainability aspects in form of PEFC (The Programme for the Endorsement of Forest Certification Schemes) and FSC certification (Forest Stewardship Council). All conducted seminars in four pilot regions (Catalonia, Western Macedonia, Estonia and Ukraine) showed a high interest of stakeholders in certification.

Certification seminars and dissemination by the project has led to successful certifications of 11 pellet producers, who opted for a product certification scheme of wood pellets for use in small furnaces in accordance with DIN EN ISO 17225-2 (A1). Ten manufactures are from Spain and one manufacturer is from Portugal.

The pellet producers were in particular interested to assure customers the quality of their product and to increase market prestige through certification schemes. The seminars were especially useful to convey market knowledge required for auditing to stakeholders, because such trainings are hard to find in schools, institutions and professional training centres.

An additional positive outcome was the successful outreach to the Carpathian Region of Ukraine, which is an important emerging market for bioenergy and already today a major producer of solid biofuels for export to the EU.

This SecureChain final report highlights various important sustainability aspects of bioenergy supply chains and adds to the communication of successful cases and good practices fit to enable broader market uptake of low carbon economy and renewable energy solutions across Europe.

2 Sustainability assessment of bioenergy pilot cases

SecureChain is a renewable energy project supported by the research and innovation programme 'Horizon 2020' of the European Union from 01.04.2015 to 31.07.2018. It was funded by the European Commission with a total grant of 1.81 million Euros. Eleven partners from ten European countries worked towards the project's goal to promote sustainable bioenergy chains in the rural area, which fulfil high environmental standards and are economically viable for SMEs. The project targeted six model regions in Europe: Gelderland and Overijssel (The Netherlands), Catalonia (Spain), Western Macedonia (Greece), North Rhine-Westphalia (Germany), Southern Estonia (Estonia) and Småland (Sweden).

This chapter presents the outcomes of WP4 Tasks T4.2 'Sustainability pre-check' and T4.3 'LCA performance check'. The progress and results of the sustainability assessment including the LCA of selected pilot project cases are reported. Further results are included in the scientific publication (deliverable report D4.4). The approach and data is documented in the Annex.

2.1 Context

The EU has ratified the Paris Agreement aiming to limit Global Warming to less than +2°C compared to pre-industrial levels. This commitment is a significant step in the direction to foster renewable energy. According to European Commission (2014b) biomass used for electricity, heating and cooling is expected to make a key contribution to reach the EU renewable energy targets. However, the provision, transport and conversion of biomass to energy also cause environmental effects. Moreover biomass is a finite resource and the balance between regeneration and deforestation needs to be stable to preserve forest health and biodiversity. For this reason, it is necessary to detect the most sustainable use of wood. Sustainable development was defined as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (Brundtland, 1987). This report presents findings from a comprehensive sustainability assessment and certification practices of 20 pilot projects that were implemented by SMEs in the scope of the SecureChain project.

2.2 Goal and scope

The sustainability assessment covers specific case studies of pilot projects which were accompanied during the project by training and coaching activities. SME owners received practical technical knowhow and advice to support broader market uptake of efficient bioenergy solutions and systems. The ambition of the assessment was to show how they can improve and provide proof of their pilot projects' sustainability. The assessment was carried out by means of Life Cycle Assessment (LCA). LCA is a standardized method (ISO, 2006a, b) to assess the potential environmental impacts associated with a product or service. An LCA includes an inventory of relevant inputs and outputs (e.g. in this case of biomass, other important materials, and energy), an evaluation of the potential environmental impacts associated with those inputs and outputs, and a critical interpretation of the inventory and impact phase's results in relation to the objectives of the study.

The goal is to gain useful insights into sustainability implementation of bioenergy systems at SME level and to consider also effects in the region. The results shall serve as a communication tool for SMEs and other bioenergy stakeholders for a broader promotion of sustainable bioenergy. Standardised methods, including LCA, ensures that sustainability of the pilot projects is quantified in a objective manner, ensuring an unbiased view of renewable energy. The comparison with a reference scenario, based on the electricity or heat mix or fossil fuel source that is being replaced by biomass/bioenergy, is conducted for each case study.

The assessment focusses on the case studies conducted within SecureChain, which were accompanied by a LCA. In total ten SMEs (out of 20) decided to take part in the LCA and provided data for the assessment. Further details about the pilot projects can be found in the other project reports, notably the Summary report and the WP3 final report D3.3 (see project website www.securechain.eu).

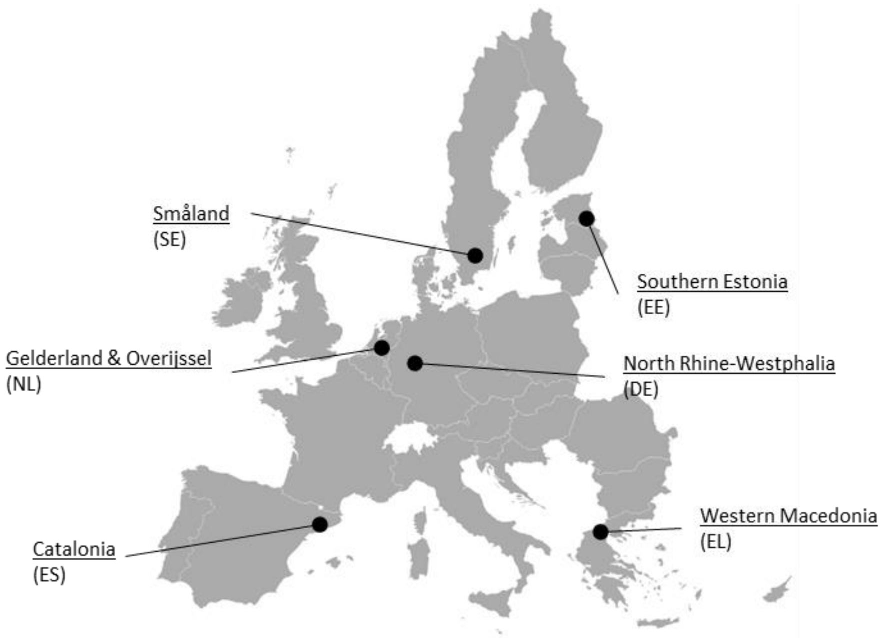

Figure 2.1: Six model regions of the SecureChain project

2.3 Materials and method

2.3.1 Sustainability approach

The main points of interest for sustainable biomass production are to ensure sustainable feedstock production, to address land use, land use change and forestry emissions (LULUCF), to assess the lifecycle GHG emission performance of biomass, to prevent indirect impacts, to promote efficient energy conversion and to minimize air quality impacts (European Commission, 2014b). Such aspects of sustainability can be assessed by specific sustainability indicators e.g. the greenhouse gas (GHG) indicator by Guinée et al. (2009). The challenge is to find the most suitable set of criteria for the study object, i.e. the case studies in SecureChain.

Sustainability has three dimensions: social, environmental and economic:

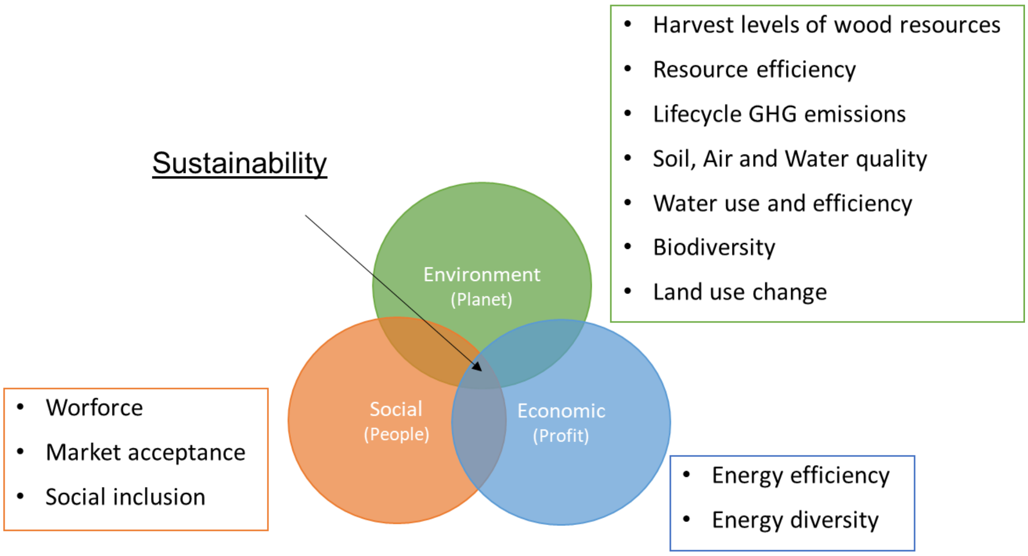

Figure 2.2: Three pillars of sustainability and selected sustainability indicators

A long list of sustainability criteria have been developed by scientists during the last decades. Sustainable forest management (SFM) criteria were adopted for the first in 1998, and then further updated in 2002 and 2015. The current set of 45 indicators define and describe various aspects of SFM in the pan-European region (Forest Europe, 2015). A number of research projects supported by European Union or national funds and policy documents make use of specific sustainability criteria.

The criteria need to be appropriate (with regard to objectivity), applicable (with regard to data and time resources) and acknowledged (e.g. consensus on method). The difficulty is to define criteria which are applicable for the entire supply chain of bioenergy (and not only forest management practices). The key question is whether they are feasible to be assessed and useful to be implemented in practice by a company. As could be shown in this study, only few criteria can be assessed in a quantitative way, while the majority can only be addressed qualitatively (see further details in the scientific publication: Obersteiner et al., 2018).

The approach in this study is aligned to the following steps:

- Comparison of the bioenergy pilot cases with a reference system (e.g. fossil energy) in a quantitative way – life cycle GHG emissions and job creation potential
- Consideration of other important sustainability criteria in a qualitative way (e.g. impacts to the soil)

The system boundary of the sustainability assessment is the entire supply chain of bioenergy, from raw material acquisition including silvicultural operations, site tending and waste treatment, e.g. ash disposal (from cradle to grave) in the forest, and the various steps of bioenergy conversion and production. Some parts/steps of the supply chain are related to the foreground and some to the background system depending on the case study (Figure 2.3).

Processes in the foreground system include the ones which are operated by the case study partner, who provided specific primary data. Processes in the background system are assessed with average values or generic data from LCA databases such as Ecoinvent (Ecoinvent Centre, 2004) or GaBi (Thinkstep, 2016)).

The case studies furthermore include different options (scenarios) which are considered depending on the specific research question. All scenarios (current, future or potential) are compared to a reference system (alternative energy). The appropriate reference system depends on the case study (e.g. in case bioenergy supplies a district heating system, then the regional district heating mix is used as a reference, in case solid biomass replaces fossil fuel in a boiler, then a specific fossil fuel is used as a reference). In other cases, the fossil fuel comparator of European Commission (2014a) was considered.

All relevant elementary flows for the indicators/criteria are covered in the system. In some cases, an up-stream process needs to be allocated to study object of a case study (e.g. if pellets produced from saw dust are the object of study, then the emissions of the saw mill are allocated to this unit).

Excluded elementary flows cover the uptake and release of biogenic carbon dioxide (CO_2). The common practice in energy related LCAs is that biogenic CO_2 sequestered through tree or crop growth, and biogenic CO_2 emitted through digestion or combustion are set to zero (Guinée et al., 2009). It is also recommended in European Commission (2014b) for bioenergy purposes (principle of carbon neutrality). However, the amount of sequestered biogenic CO_2 that is released as methane (CH_4) is considered. The ecoinvent database used in SecureChain distinguishes between fossil CO_2 and biogenic CO_2.

Details on the foreground system of each case study, the applied scenarios and the justifications can be found in the Annex chapter of each model region.

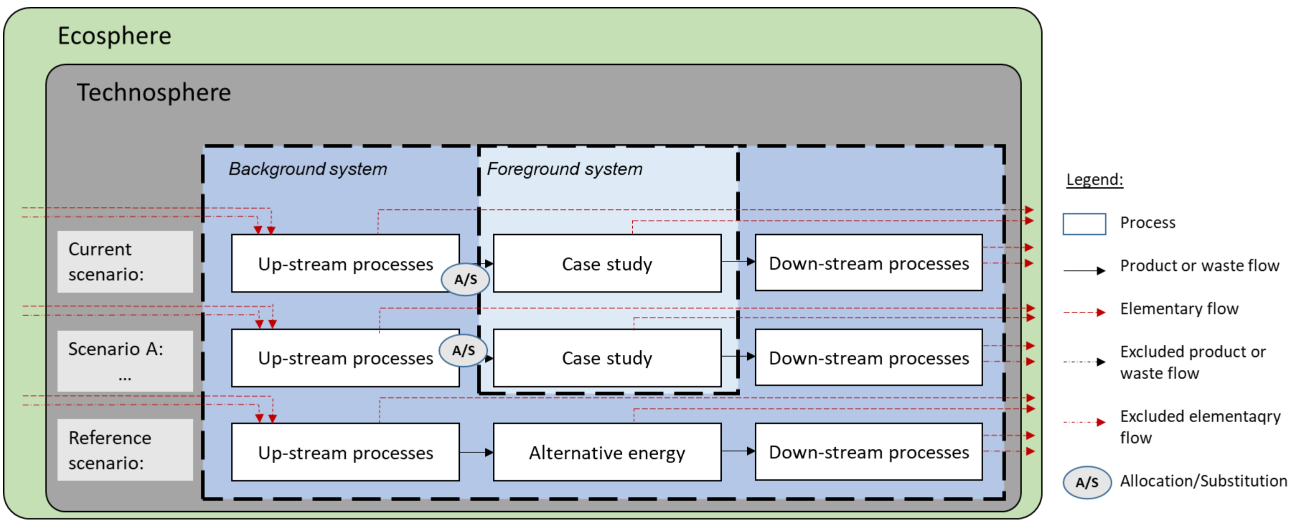

Figure 2.3: Foreground and background system of the study (illustrative)

2.3.2 Quantitative criteria

2.3.2.1 Life-cycle GHG emissions

The most widely used impact category in existing LCAs of bioenergy is the Global Warming Potential (GWP). GWP is widely applied for the assessment of the contribution of greenhouse gases (GHG) to climate change. It is used in LCA, but also in the United Nations Framework Convention on Climate Change (UNFCC) and the accounting under Kyoto Protocol (Brandao et al., 2013). At midpoint level, the GWP is expressed in kg CO_2-equivalents (kg CO_2-eq.).

The method to evaluate the life cycle GHG emissions is based on principles of LCA. The modelling framework follows an attributional approach[1].

The data inventory was carried out by the project consortium in direct contact with the SMEs. The research partner CERTH supported specifically the case study in Western Macedonia, Greece. The data collection included also site visits t of the SMEs and meetings with the SME partners to define jointly the system boundaries and research questions. Data was collected via inventory sheets provided by BOKU and in other available forms (e.g. Excel files, E-mails). To ensure confidentiality, detailed inventory data is not presented in this report.

The calculated life cycle GHG emissions of the bioenergy system are used to define the 'GHG indicator'. It is expressed as the reduction of GHG emissions of a bio-based fuel chain in comparison with a fossil-based fuel chain (Bergsma et al., 2006; Guinée et al., 2009). If LCA data was unavailable to calculate the GHG indicator, default values of Giuntoli et al. (2015) were considered as estimate.

$$\text{GHG emission savings} = \frac{\text{Total GHG emissions of fossil fuel} - \text{Total GHG emissions of bioenergy}}{\text{Total GHG emissions of bioenergy}}$$

Figure 2.4: Formula of GHG emission savings, 'GHG indicator'

2.3.2.2 Regional job creation potential

The regional job creation potential gives information about the amount of green jobs being created as a result of increased bioenergy, and can be compared to jobs involved in fossil-based energy systems. The main difference is that in the case of bioenergy, a significant number of workforce (e.g. for acquisition of feedstock, processing of energy carriers) stays within the region, whereas in case of fossil energy systems, those steps of the supply chain occur to a very large extent in another economic area (or even another continent).

[1] Research questions of the case study LCAs focus on the performance of a system, which can be referred to carbon accounting, a typical attributional approach. On the contrary, consequential LCA covers the change in a system, including effects on the market. These effects are not quantified in this study. However, we want to emphasize that those are of high importance to sustainability, which is why consequential thinking is also covered in qualitative criteria (see 2.2.3).

The indicator ‘Job creation potential’ refers to the social dimension of sustainability and can be allocated to the stakeholder category ‘local community’ (local employment) (UNEP, 2009). The social dimension of sustainability can be assessed by the method of social life cycle assessment (S-LCA). Two classification schemes are apparent in social LCAs: analysis in a stakeholder based framework and in an impact category framework. Both should be considered complementarily (Benoît-Norris et al., 2011; UNEP, 2009). Stakeholder categories are worker, consumer, local community, society and other value chain actors (UNEP, 2009). Job creation is one of the mid-point indicators within the impact category framework. The causal model to link mid-point to end-point indicators (e.g. in case of job creation → changes in health) is still complex. Furthermore, a balance between accuracy and uncertainty need to be considered. Experts agree that mid-points are the best proxy (Benoît-Norris et al., 2011). Therefore, the assessment in this study is also limited to the mid-point indicator.

For the purpose of this study, the job creation potential of the different bioenergy scenarios along the entire biomass supply chain are compared with the job creation potential of the reference (fossil-based) scenarios.

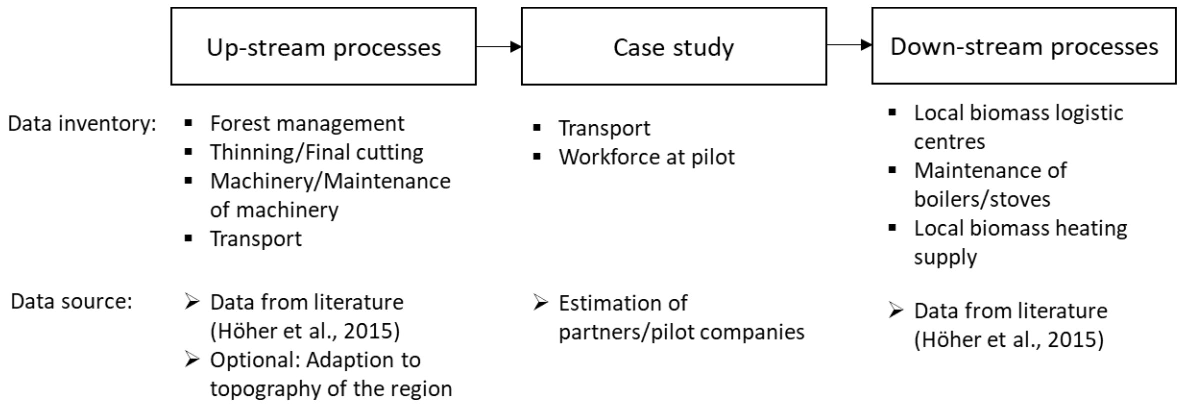

Figure 2.5: Approach for calculating the job creation potential

Data inventory for the assessment of the midpoint category Job creation derives from both primary (estimations from case study partners) and secondary sources (see Figure 2.5).

2.3.3 Qualitative criteria

Besides lifecycle GHG emissions and job creation potential, several sustainability criteria were assessed in a qualitative way. They were selected based on their relevance for the case studies, but there was no means to quantify them.

From a forest resources point of view, the harvest levels of wood resources, more concretely the ratio of annual increments and annual fellings of wood in forests available for wood supply within a country was considered. Data on this indicator are available from Eurostat on country level and was used to assess if a balance between increments and fellings is apparent in a country. (even though it has to be acknowledged that the situation on regional level may look different than on national level). Furthermore the type of biomass used in the pilot cases was considered. A country showing a felling level that exceeds the increment, but which mobilises new feedstock (e.g. material from maintenance practices of landscape elements), was assessed positively.

Furthermore, sustainability indicators on forest or wooden land ecology were examined. In the case of energy crops, the indicators soil and water quality, water use and efficiency as well as land use change are important, and should not be neglected. The indicator air quality is of major relevance in case of bioenergy due to the release of particulate matter or air emissions due to incomplete combustion processes. Besides greenhouse gas emissions, the combustion of biomass also produces other emissions to the air, which are relevant for human health and natural environment. Incomplete combustion produces harmful pollutants such as particulate matter (PM), heavy metals, polycyclic aromatic hydrocarbons, non-methane volatile organic compounds, persistent organic compounds and carbon monoxide. Household solid fuel combustion has traditionally been the major source of particulate emissions in the EU due to incomplete combustion (approx. one third of all EU-27 PM emissions) and linked to respiratory health problems (European Commission, 2014b). NO_X emissions are especially relevant for air pollution. Nitric oxide (NO) and nitrogen dioxide (NO_2) contribute to the formation of smog and acid rain, as well as tropospheric ozone. They are considered in impact categories like Acidification potential (AP) and also terrestrial Eutrophication Potential (EP). Dust and ash particles are quantified under the indicator particulate matter in kg PM 2.5-equivalents. Quantitative data for the pilot cases was however not available. The indicator air quality was therefore only considered in a qualitative way.

Biodiversity is important if major interference occurs on forest land as a result of bioenergy production. The type of biomass also needs to be considered: if primary forest resources are used, biodiversity is more affected by bioenergy practices than if secondary forest resources (e.g. saw dust) are used.

Regarding the social pillar of sustainability, market acceptance was selected besides the job creation potential as relevant indicator. Some practices in the pilot cases led to an increase of market acceptance (e.g. if wood chips are upgraded to pellets) which however require more efforts during processing, and consequently more GHG emissions. However, it is an important factor and needs to be considered when interpreting the results.

Social integration and cohesion should also be part of a sustainability assessment, and shall guarantee adequate and decent social protection, combat social exclusion and poverty and improve working conditions. One of the ambitions of the EU's Circular Economy Package (European Commission, 2015) is to create opportunities for social integration and cohesion as an added value to the region. This indicator was considered in a qualitative way.

From an economic view, energy efficiency is the main important indicator. Data on energy efficiency was not always available for pilot cases, which is why this indicator was only considered in a qualitative way. Furthermore, energy diversity is another important aspect on regional scale. If energy diversity can be increased by solid biomass, it leads to more energy security and consequently energy independency. The assessment of this indicator was based on Eurostat data on primary energy production (Eurostat, 2016) and the share of renewables and solid biomass in each country.

2.4 Results

2.4.1 Case studies to mobilise biomass at regional scale

The mobilisation of biomass at regional scale can be driven by several options. Either induced by infrastructural changes (e.g. installation of a biomass plant for district heating system) or by economic factors and policy decisions (e.g. subsidies for 'green' electricity), such interventions are aimed to lead to an increased mobilisation of biomass in the region. The selected pilot case studies show a wide range of options to mobilise biomass. However, all can be grouped under *infrastructural interventions*, because this is the area that companies can influence directly. It represents the *foreground system* for the LCA, for which also primary data can be obtained from the companies. To allow a better structural understanding of the case studies involved, the scenarios used in the case studies and the LCAs were grouped to specific 'areas for action'.

2.4.1.1 Sustainable company enlargement

The pilot case of **Novalia (ES.3)**, a major pellet manufacturer in Catalonia, is about the enlargement of its pellet production from approx. 20,000 tons per year to 65,000 tons per year. A CHP plant, which is fuelled with gas oil and fuel oil, provides heat and electricity to the electricity grid, to a district heating system and to the pellet production process. The CHP plant creates enough heat to enable the enlargement of the pellet manufacturing (process heat is needed for drying the material). Therefore, when more heat can be used, the general energy efficiency of the CHP plant increases. However, as long as the fuel is still coming from fossil sources, also the carbon footprint will be increased.

The LCA showed that 80 to 89% of the GHG emissions derive from the heat produced in the CHP plant, which is mainly fuelled by light fuel oil. Transport, packaging and electricity have a small share of the total impacts. The share of the biomass feedstock of the total impacts ranges from 2 to 11%, depending on the relation of wood chips and saw dust. The environmental impacts of the feedstock were allocated to wood chips and sawdust based on the economic value in relation to sawn timber, which is the main product of a sawmill. Depending on the considered price scenario (low-end price or high-end price for sawn timber), the impacts have a greater share versus a lower share. As described before, the more sawdust is used, the better for the overall environmental results.

However, most of the impacts still derive from the fossil fuel use for heat generation. The company though has already plans to supplement the fuel with biofuel sources, such as animal fat and biodiesel. Nevertheless, for the LCA two scenarios are compared. One scenario A is about the company enlargement with process heat from fossil sources and scenario B exemplifies the process heat coming from renewable sources. Scenario A results in a GHG saving potential by only 22% compared to a fossil based scenario. Scenario B results in 86% GHG savings. So with regard to GHG emissions, the process heat from renewable sources is clearly favoured solution. Even though the process heat is now used more efficiently which makes the process in general more energy efficient, it is still based on fossil sources, which needs to be considered when calculating life cycle GHG emissions. Therefore a switch from fossil to renewable sources for the provision of process heat is recommended in this case.

Nevertheless, other sustainability criteria can be fulfilled with this pilot case. Wood chips and saw dust are provided by nearby sawmills, which fosters the national resource availability. Wood chips and saw dust furthermore count as secondary forest residues, which increases a more efficient use of the resource forest wood. Furthermore, regional jobs can be generated through the provision of forest wood to sawmills, the pellet production, and the maintenance of pellet boilers at end-consumers (in total approx. 28-55 FTE per year), which exceeds the regional jobs in a fossil scenario that are mainly limited to the maintenance of oil-fired or gas-fired boilers (9 FTE per year). If the process heat used for pellet production can be supplied additionally with renewable sources from e.g. nearby sawmills, the regional job creation can further increase.

Furthermore this pellet manufacturer produces pellets in EN plus quality, which strengthens market acceptance. Energy efficiency is increased with the increased pellet production as more process heat from the CHP can be used compared to the status quo. The provision of pellets as a renewable source increases also energy diversity in the region. Although the primary energy production in Spain already has a high share of renewable sources (52% according to Eurostat data from 2018), the share of solid biofuels is only 16%. Energy security can thus be increased in case solid biofuels are used supplementary to wind and solar.

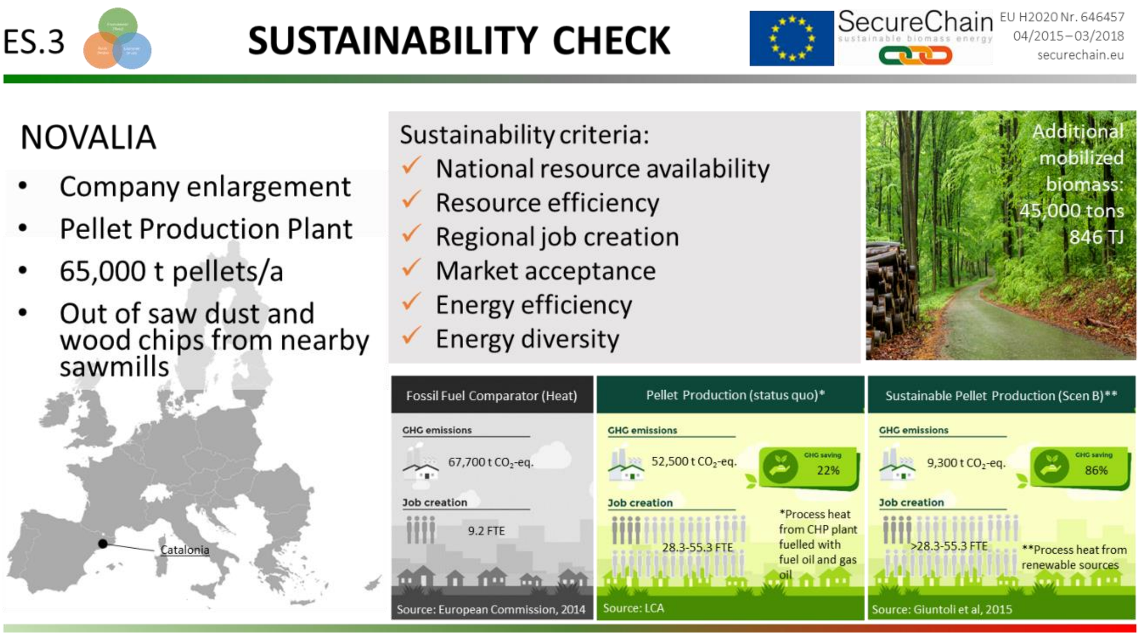

Figure 2.6: Sustainability check of pilot case ES.3 Novalia

2.4.1.2 Acquisition of new regional feedstock for bioenergy

New pathways for bioenergy were implemented in several case studies in the Netherlands, were landscape maintenance residues from hedges, single-line tree stands, small forests and parks are mobilised for bioenergy. Furthermore in the case study in Germany, trials with solid biomass separated from collected biowaste were carried out to generate more bioenergy. In Greece the pilot investigated bark from forestry residues as source for bioenergy to replace valuable wood that can be used for medium-density fibre (MDF) board production.

The pilot project of the company **Bruins and Kwast (NL.3)** investigated to up-grade their production of wood chips from landscape elements towards a production of pellets in order to increase consumer and market acceptance. A LCA quantified the GWP of pellets produced from landscape maintenance residues (brand name “Streekpellets”) and compare them to pellets produced from sawmill residues imported from Germany, which are currently the most common form of pellets consumed in the Netherlands. GHG emissions for 1 t of pellets, which are equal to 15.9-16.5 GJ/t (LHV) result in 60 kg CO_2e. Most emissions are associated with electricity required for the pelletising process (56%) and the chipping of the landscape material (19%). Harvesting represents 4%, transport of woodchips to the pelletising plant 9%, sizing and drying 2%, and transport to the consumer 10%. The results show that Streekpellets represent only half of the GWP compared to pellets made from sawmill residues and imported from Germany. This is mostly due to emissions associated with transport (see Annex). Compared to a fossil fuel scenario, Streekpellets emit 94% less GHG emissions.

Streekpellets are produced from landscape maintenance residues. The total annual increment of the landscape elements is substantially higher than the amount of material currently being harvested. The used biomass resource is therefore not considered as critical. Resource efficiency is also ensured, because low quality wood from landscape elements is used, and not from forests. The ratio of Netherland’s forest wood increments and fellings for wood supply is 100% (Eurostat, 2015a), therefore landscape elements foster the acquisition of solid biofuels without impacting on the forests.

Regional job creation can be improved by the pilot up to 5.8 FTE, much more than compared to the fossil scenario with only 1 FTE. Furthermore, consumer and market acceptance can be increased, as a non-forest wood resource is used and additionally upgraded to a well-defined, appreciated fuel source. The energy efficiency of the process is controversial, because a lot of effort is required to produce pellets from landscape elements, instead of simply chipping the material. However, the efforts need to be balanced with the increased market acceptance. The higher efforts are in this case acceptable if the market acceptance is strongly improved. The pilot also contributes to more energy diversity, because the share of solid biofuels on the primary energy production in the Netherlands is currently only 3% (Eurostat, 2016).

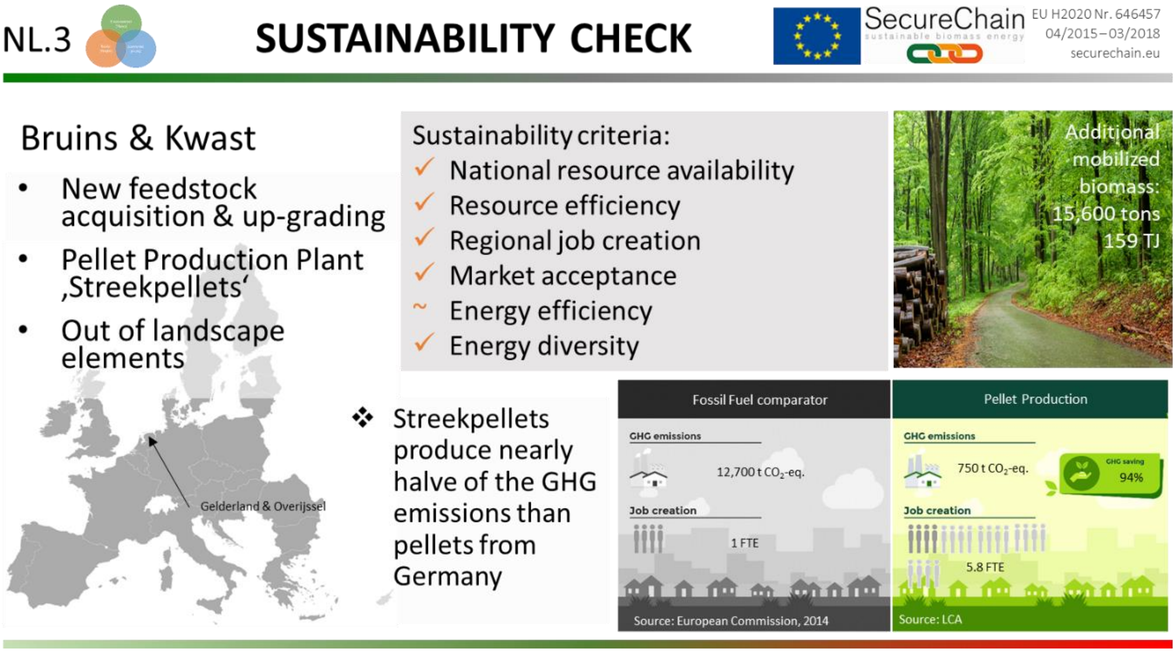

Figure 2.7: Sustainability check of pilot case NL.3 Bruins & Kwast

In the Dutch pilot case of the company **Hissink & Zonen (NL.1)**, a new machine was tested that combines the collection, chipping and transportation of branch and top wood in one stage. The aim was to make the biomass segment branch and top wood more accessible and the harvesting more efficient. In the LCA, the new machine was compared with the current harvesting practice (i.e. a forwarder for collection and a chipper for comminution of branch and top wood). The LCA shows GHG savings of 18-25 kg CO_2eq Mg DM^{-1} of the new machine in comparison to the current situation. However, the pilot case was not further implemented by the company for internal reasons. Therefore, apart from the LCA, no further sustainability assessment could be conducted here.

The second Dutch pilot project carried out by the company **Ribo Holding (NL.2)** aimed at strategic biomass storage facilities for landscape maintenance. The goal was to increase wood chip production from prunings by improved strategic storage facilities to ensure that wood chips can be marketed at the best possible value. A LCA was not conducted here. However, the pilot project was implemented and an additional biomass of 200 tons respectively 1620 GJ can be generated. The calculation of the GHG savings compared to a fossil reference system without LCA data is difficult here, as default values of Giuntoli et al. (2015) do not consider landscape elements. If GHG emissions of wood chips from forest residues are considered as an alternative but comparable resource, a GHG savings potential of approx. 120 tons CO_2-eq. compared to a fossil reference system can be expected of this pilot project.

Apart from the saved GHG emissions, the optimized process to acquire additional biomass can lead to an increased energy efficiency. Similar to the pilot case NL.3, the use of landscape elements performs well for criteria such as national resource availability and resource efficiency. Regional jobs can be created by this pilot, but the quantification was not possible due to a lack of sufficient data.

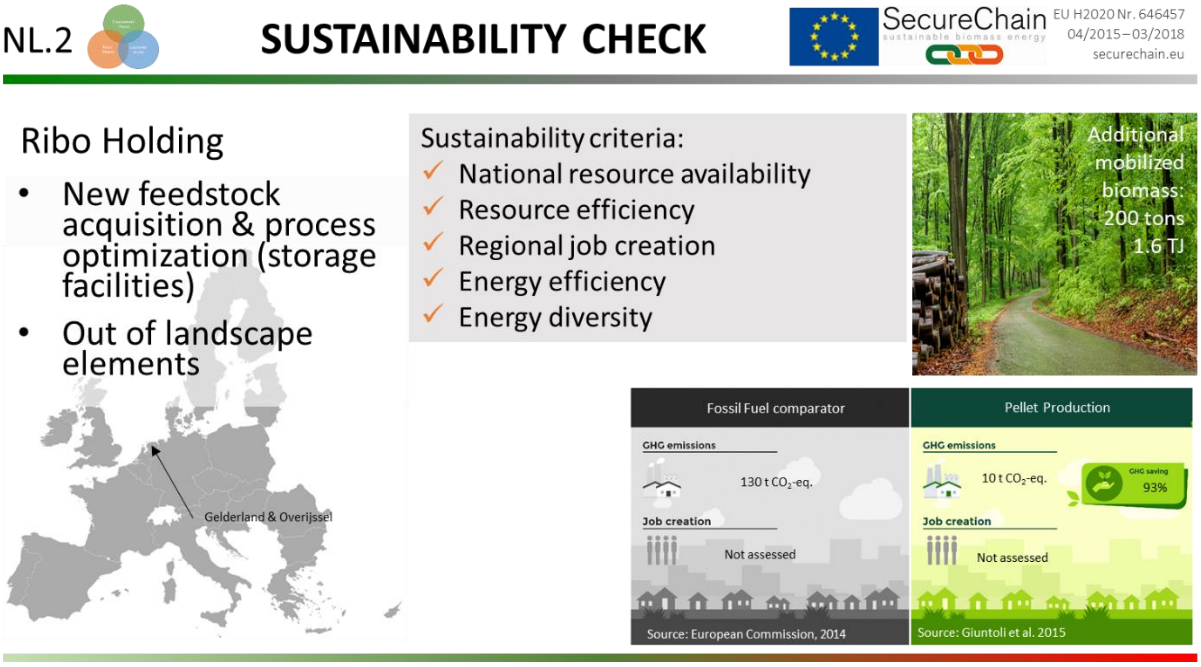

Figure 2.8: Sustainability check of pilot case NL.2 Ribo Holding

The pilot case initiated by the company **AVEA (DE.2)** in Germany showed that additional biomass can be mobilised from garden and yard waste. A new sieving step for biomass was established in addition to the current process involving shredding, rotting and sieving. The process of AVEA was investigated using a LCA, which revealed that most of the direct emissions come from the rotting process of biodegradable material. Through the initial sieving step, more biomass can be separated from garden and yard waste, which reduces the amount of material in the rotting process. Direct emissions in the rotting process can thus be reduced by about 11 %.

In the case of biomass acquired from garden and yard waste from households, emissions from the up-stream process (e.g. cutting garden and yard waste) do not need to be attributed to the process[2]. Only process emissions, in this case the shredding and the sieving were considered. Compared to emissions of the use of fossil sources, the emissions from shredding and sieving were with 2.6 g CO_2-eq./t biomass almost neglectable. The GHG saving potential is therefore 100%, if biomass acquired from garden and yard waste is used for electricity and heat. This new required feedstock further increases the independence of wood supply for bioenergy from forests and increases resource efficiency. Energy efficiency of the process is increased because biomass can be used to generate heat and electricity. There is no difference between direct jobs created in the status quo and the pilot scenario. The influence on indirect jobs compared to jobs created by fossil sources on regional level is assumed minimal. Energy diversity can furthermore be increased. Currently 34% of primary energy production in Germany derives from renewable sources and 11% from solid biofuels. The pilot case of AVEA shows the potential of additional biomass acquisition for bioenergy from wood wastes.

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[2] No up-stream emissions are accounted for waste materials below a zero market value in LCAs.

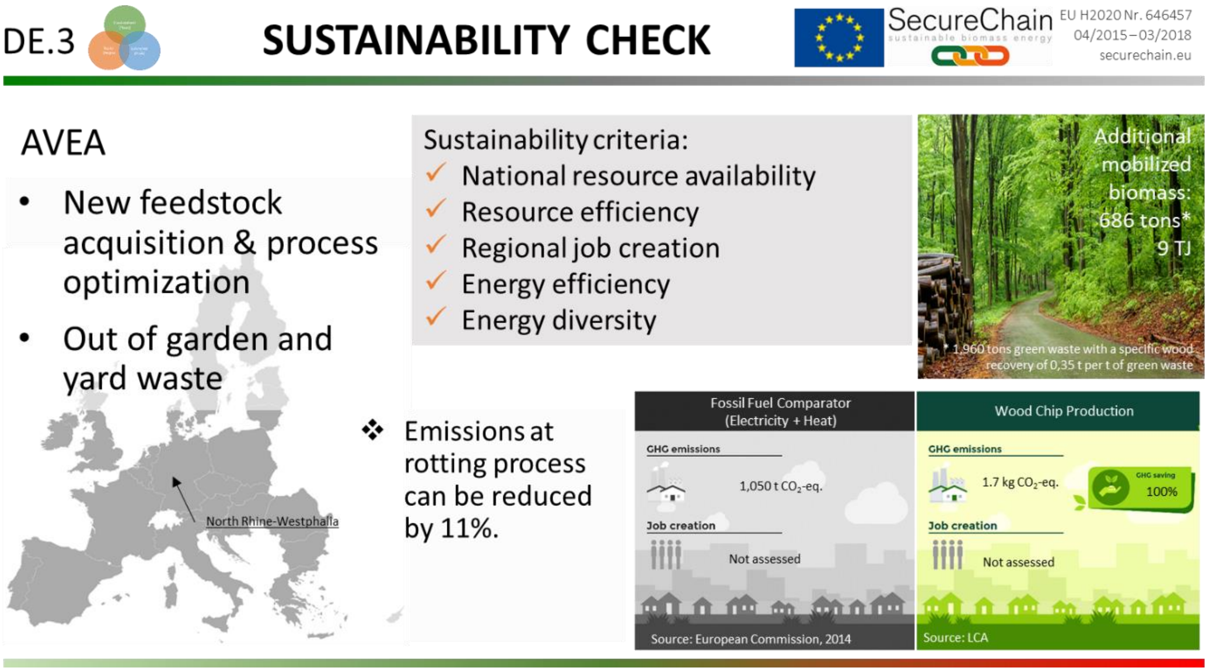

Figure 2.9: Sustainability check of pilot case DE.3 AVEA

Another example for new feedstock acquisition is the pilot project of **EL.2 Alfa Wood – Pindos SA**, a producer of medium density fibreboards (MDF) in Western Macedonia, Greece. To provide heat energy for their production line, two thermal oil boilers are located on-site, which run on bark and wood chips. The heat of the flue gas is used for the MDF production process and also for heating of offices during wintertime. Electricity is currently not produced. The wood chips currently used as feedstock for the thermal oil boiler could also be used for MDF production. This is why the company intends to mobilise more bark as feedstock and use valuable wood chips in their MDF production lines instead.

The bioenergy production at Alfa Wood gains at the moment GHG savings of 88% compared to the fossil reference system. For a further improvement of the environmental performance, the feedstock input could be enlarged from 80% to 90% or even 100% bark, which would result in additional GHG savings of 2 to 4%.

However, a different composition of the feedstock in the combustion process can also result in different emissions to air. The use of more bark could have the effect that more NO_X emissions are produced as more nitrogen is contained in bark. It is recommended to look at the emissions and the influence, when more bark is combusted. Furthermore, it has influences on the carbon stock in the forest. The acquisition of more bark during harvesting leads to less bark left remaining on the forest floor, which can influence soil quality and biodiversity in forests. However, regarding resource use, wood from forests is used efficiently, if the bark is used for bioenergy as a residue from production (cascade utilization), because bark replaces in this case high value wood chips which can be used for MDF production instead.

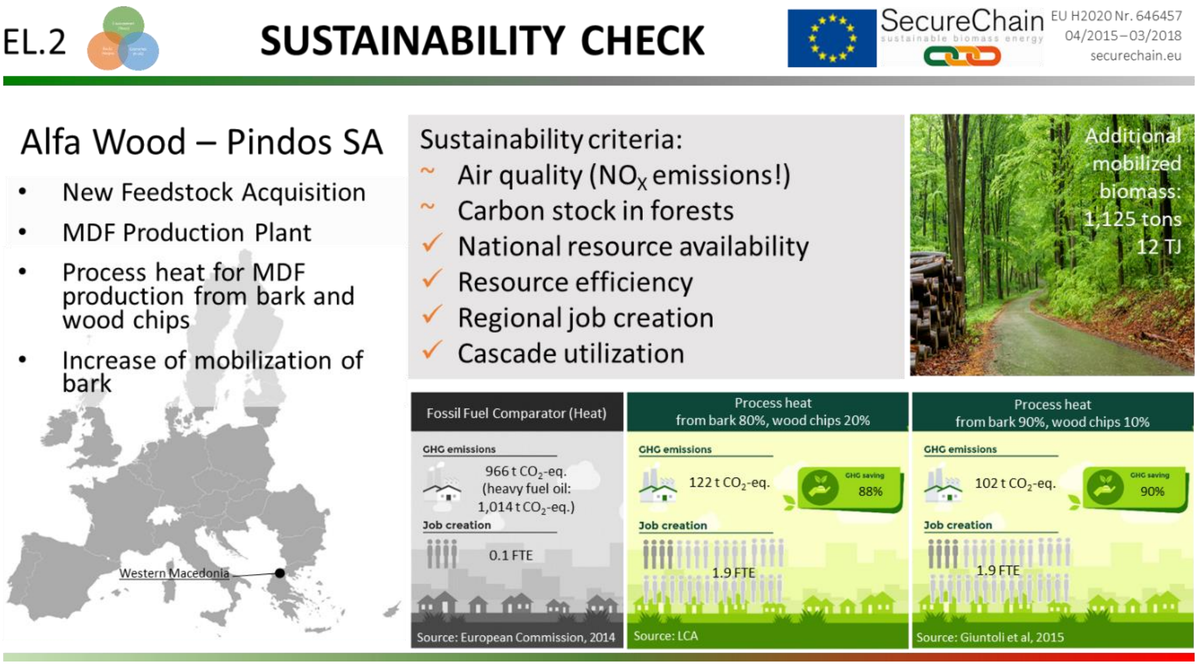

Figure 2.10: Sustainability check of pilot case EL.2 Alfa Wood – Pindos SA

Energy crops are another possibility to acquire new feedstock. However, increased inputs for feedstock production such as fertilizer and water use need to be taken into consideration to evaluate the environmental performance. The pilot case of **EL.1 AZ Bioenergia** produces biomass by means of *short rotation coppices* (Paulownia species). This fast growing tree species is tested on a total plantation area of 6400 m^2 in a region near Kozani in Western Macedonia, Greece. Part of it is also planted for timber production. Energy is planned to be produced via a combined heat and power plant. The produced biomass shall be used in this CHP plant. The produced electricity will be fed into the grid and the produced heat will be used for greenhouses to grow paulownia plants.

The test harvesting of the plants could not be conducted before the end of the project. Therefore, data on harvesting and consequently on biomass yield is lacking. The specific biomass yield could only be estimated based on figures from existing comparable plantations in Spain. However, fertilizer and water use of the plantation were documented during the first four years. As it is a test area, which is still quite far from agricultural practice for energy crops, the optimal amount of fertilizer and water use may vary from the future practice. Therefore, the LCA results can only be considered with high uncertainty.

Nevertheless, at medium and maximum biomass yield, the emissions are lower compared to the fossil reference scenario. The biomass yield is therefore of upmost importance to generate GHG savings compared to the reference scenario. Impacts of the provision of the feedstock derive mainly from the efforts during growing of the trees, which is application of fertilizer and water, as well as mechanical removal of weed.

Furthermore, the effect of GWP after the whole lifetime of the trees is hard to estimate. An important fact is that the influence of plantation is low compared to the efforts during growing of the tree, so that the GHG emissions per MJ_{th} is comparable to the results after the first cut.

Apart from the lifecycle GHG emissions, other sustainability criteria are of high relevance in this case. Fertilisers play a crucial role to direct field emissions. Primarily fertilisers should cover the needs of the plants. Nutrients (N, P, K, Ca, etc.) supplied to the soil are either exported to the products or lost to the air or water. The intensive use of mineral and organic fertiliser can create various environmental impacts, such as emissions to air (ammonia, nitrous oxide, nitrogen oxide, carbon dioxide), emissions to water (nitrate leaching, phosphorus leaching, heavy metals) as well as emissions to soil (nutrient inputs to soil, heavy metals). Fresh water is used via a drop irrigation system, which is efficient in use, but the supply is unavoidable to enable the growing of the trees in that area.

Furthermore, as the test area is situated on arable land, there can be competition to food production. Therefore it is planned to expand such plantations on depleted lignite mines to avoid this competition. The disadvantage is, however, that depleted lignite mines are not as fertile as arable land. So additional fertilizer input may also be required. Consequently, the environmental performance needs to be analysed again when more data will be available on the actual practice considering the many crucial factors. This is important to determine if the system is sustainable or not.

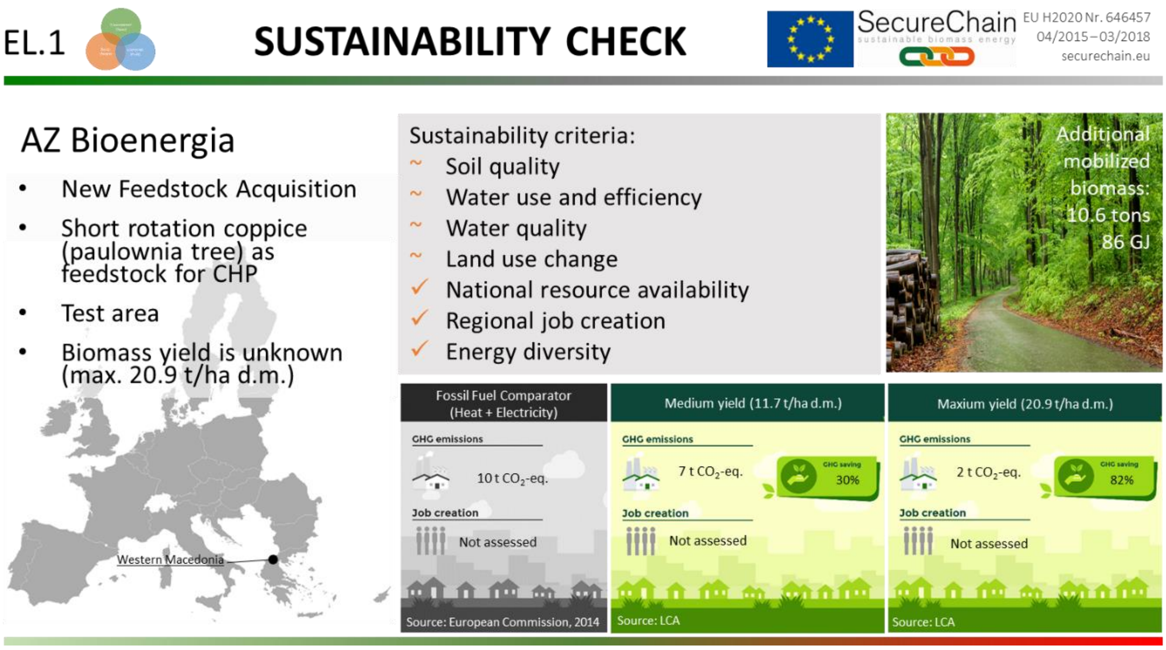

Figure 2.11: Sustainability check of pilot case EL.1 AZ Bioenergia

The pilot project of **EL.3 Matesion** addresses efforts to establish a well-structured biogas supply chain that could better address the feedstock of biogas plants in the region of Western Macedonia as well as to better handle animal manure and agricultural biomass residues. The substrate mix was improved during the pilot to increase biogas yield and to reduce down periods. Consequently, the capacity factor of the biogas unit increased from 5,500 to 7,500 hours/year, which resulted in a final energy production of 3 TJ/year. An additional energy amount of 660 GJ could be generated by this intervention which results in GHG savings of 75 tons CO_2-eq./year according to default values of Giuntoli et al. (2015).

Furthermore, air quality is strongly influenced. The application of undigested manure to land creates more emissions to air than digested manure, which is a clear benefit when using manure as a substrate in biogas plants. National resource availability is given and resource efficiency increases if substrates such as vegetable oil or manure are used to generate energy instead of being wasted or discarded onto land. However, the use of digestate as a fertilizer is still a constraint in that area, which makes market acceptance of this kind of product insecure.

Energy efficiency can be optimized in the biogas plant, as currently electricity is produced and fed into the grid and heat is only used internally. A further use of heat (provide heat to another consumer) can increase energy efficiency and also cost efficiency. Furthermore, energy diversity is increased in a region where most of the heat is provided by the fossil fuel lignite.

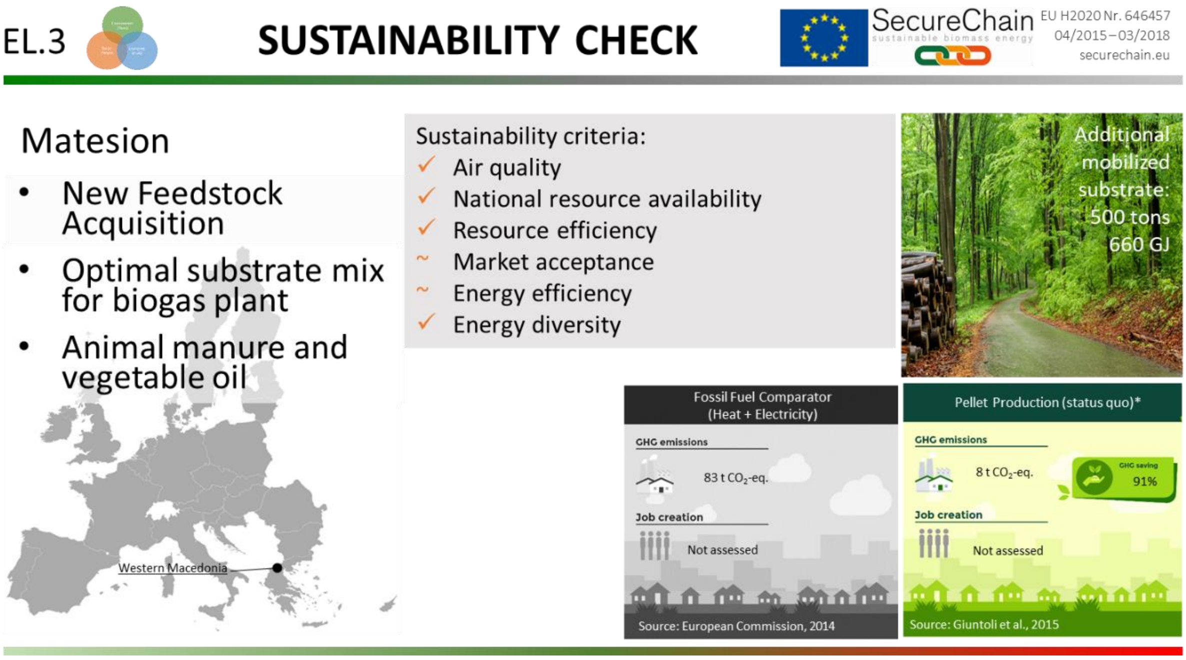

Figure 2.12: Sustainability check of pilot case EL.3 Matesion

2.4.1.3 Logistical changes to reach more customers

Interventions in delivery logistics can increase accessibility to customers, which was tested in two pilot projects. Strategic storage facilities for wood chips are established in the pilot projects of NL.2 Ribo Holding and of ES.1 Sala Forestal. As the wood chips in the NL pilot project are generated from landscape elements, the sustainability performance is shown in the respective chapter 2.4.1.2.

In the pilot project of **ES.1 Sala Forestal**, the radius for customers is expanded via the establishment of storage tank stations in the surroundings. Big transport vehicles are taken to transport the fuel to storage tank stations, where the further delivery can take place by small transport vehicle. The assessment of the environmental performance of the case study Sala Forestal is limited to logistical issues. Emissions from production and maintenance of transport vehicles, production and operation of storage tanks, and end of life treatment of these are not considered. Therefore, no life cycle approach in the sense of a LCA is applied here.

The total GHG emissions for the current distribution system resulted in 20.21 kg CO_2-eq. per ton transported wood chips, and for the distribution system in the pilot in 12.39 kg CO_2-eq. per ton transported wood chips. The improved distribution concept of Sala Forestal can therefore achieve a reduction of GHG by 40% compared to the status quo. It needs to be kept in mind that the GHG reduction potential only covers emissions from the transport processes.

However, this concept enables an increased accessibility to customers, which can lead to an increased mobilisation of biomass. In the pilot study an additional biomass amount of 8700 tons was mobilised which result in a final renewable energy production of approx. 99 TJ. If default values for wood chips are used out of Giuntoli et al. (2015), it results in GHG savings of 93% in comparison to fossil energy system. As the pilot case is limited to logistical issues the resource availability or efficiency of the wood chips used in this company cannot be assessed.

However, this pilot case has an effect on direct and indirect job creation due to the expansion, which is very high compared to the regional job creation of the fossil reference system. The consumer acceptance is also estimated to be increased by the pilot, as it is more convenient for customers now to gather wood chips from automatic and remotely controlled solid biofuels dispensers. As the logistical processes are optimized, and logistical pathways are shared with other transport companies, it is in general positive for the energy efficiency of the system. Furthermore, as more wood chips are distributed to end-customers, the energy diversity in the region can also be positively influenced.

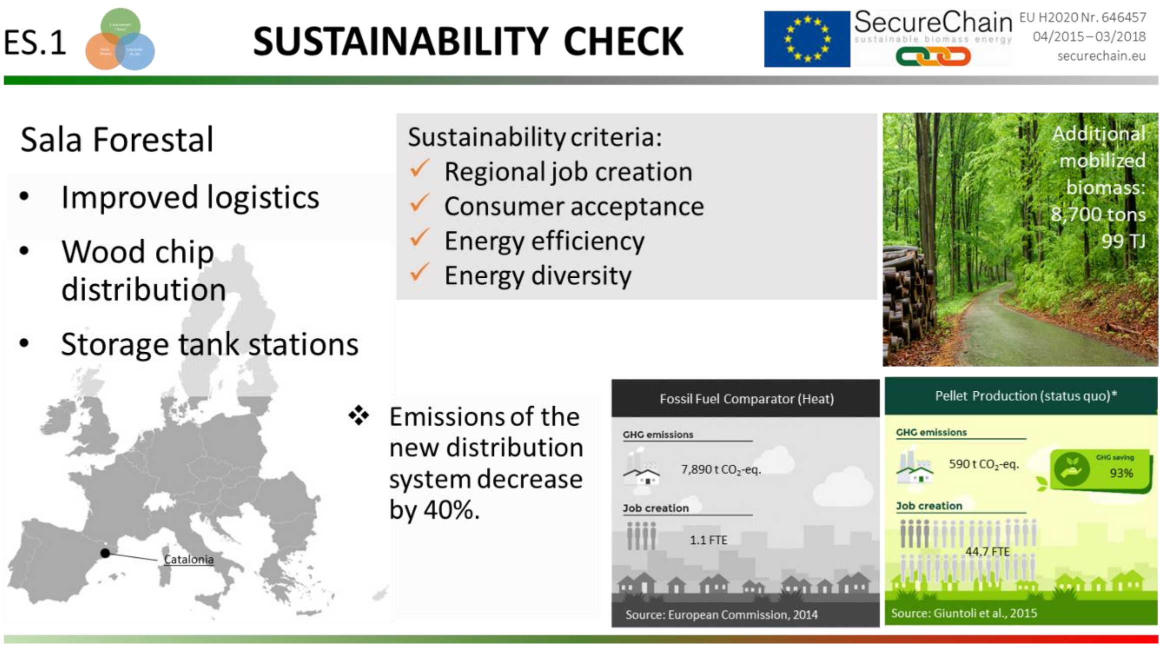

Figure 2.13: Sustainability check of pilot case ES.1 Sala Forestal

2.4.1.4 Replacement of fossil fuel boilers

The replacement of fossil fuel boilers with biomass boilers is a prominent measure in energy strategies on national level to foster renewable energy (e.g. ban on oil heating implemented by the Danish Energy Association). It is also the goal of several case studies in SecureChain. A company in Catalonia thrives towards the replacement of fossil fuel boilers (natural gas and oil boilers) in public facilities at their local area with solid biomass boilers. A second case study in Sweden aims to substitute oil boilers at small communities with pellet or wood-chip boilers and to connect them to a district heating system.

The pilot case of **ES.2 La Fageda** covers many steps of the biomass supply chain from wood extraction from local forests to the use of wood chips at in-house boilers and in boilers at other public facilities (replacing fossil fuel boilers) in the area. Forestry works are carried out by company staff, but are currently economically not feasible. The environmental effects are however significant, because various natural gas and oil boilers currently installed in public facilities could be replaced by biomass boilers and supplied with regional biomass which saves GHG emissions by 93%. Furthermore, the forestry works carried out by La Fageda do not only increase the job creation potential and added value in the biomass sector of the region, but it also integrates mentally deprived people, which increases the social value of this pilot project.

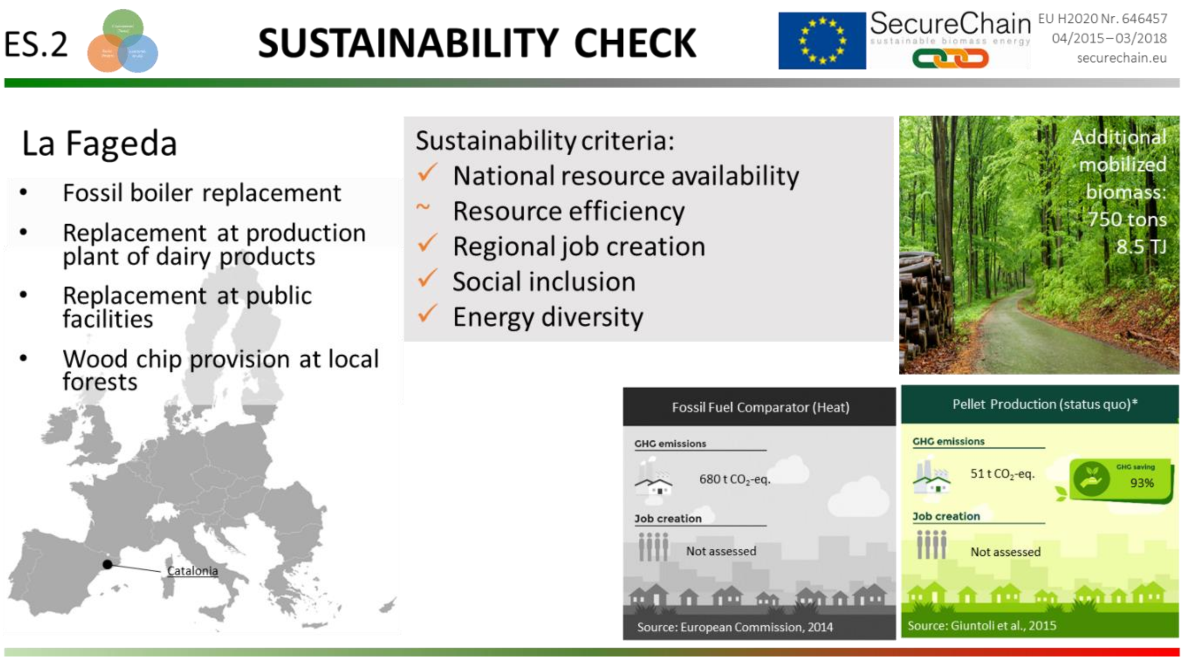

Figure 2.14: Sustainability check of pilot case ES.2 La Fageda

The pilot project of **SE.2 Värnamo** aims to optimize modern biomass boilers for small communities by finding the best biomass solution to substitute oil fired boiler. Värnamo Energi AB, wholly owned by the municipality of Värnamo, and Finnvedsbostäder are the two main providers of district heating (DH) in various communities nearby the city of Värnamo. Several of the local oil-fired boilers need to be modernized or exchanged in the next few years, so it is a great opportunity to develop a sustainable biomass- based energy system and convert to more environment-friendly fuels. The goal of the providers is on the one hand to offer external customers a bio-fuelled heat solution and on the other hand to reduce the share of oil to maximum 5% of total energy input, use it only as a reserve during maintenance operations, annual boiler inspection and mainly for unplanned downtime.

The objective of the study is to find the best alternative biomass solution, especially looking at wood fuels (pellets or chips) for the further oil-fired boilers that are in need of renovation. To support the pilot project with environmental considerations, average GHG emissions of existing LCA studies in Swedish or Scandinavian context were compiled. The review resulted in 3.25 g CO_2-eq./MJ given on average for wood chip production and combustion and 3.35 g CO_2-eq./MJ on average for pellet production and combustion. Except for combustion emissions, no clear differences between wood chips and pellets were observed. Outcomes depend on transport distances, availability of resources (e.g. sawdust vs wood chips), storage capacities, waste heat that could be used for drying pellets etc. Default values for wood chips in Giuntoli et al. (2015) are higher.

As mentioned further above, LCA of bioenergy is very context specific. Therefore, it is hard to directly compare pellet versus wood chip fuelled boilers, because results are depending on many factors (type of raw materials, moisture content, transport distances, storage capacities, fuel for drying). A general recommendation can indeed not be given. However, in direct comparison of the described scenarios, combustion emissions of pellets are lower compared to wood chips, mainly due to its lower ash content and better combustion ability.

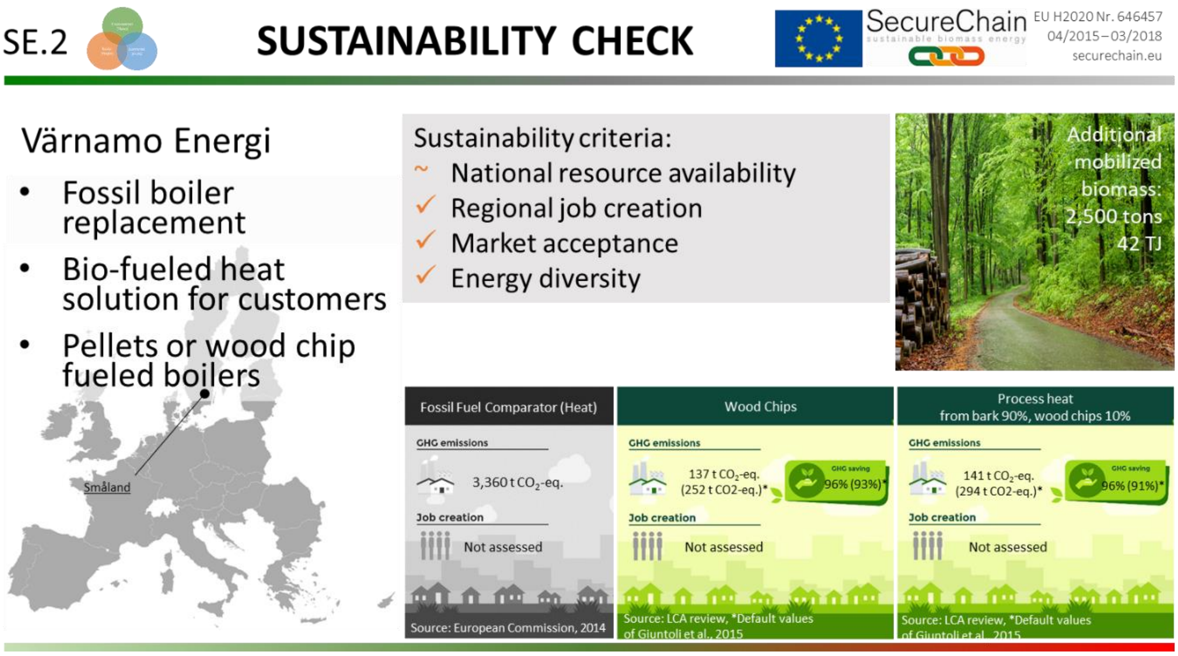

Figure 2.15: Sustainability check of pilot case SE.2 Värnamo Energi

2.4.2 Case studies to increase resource efficiency

The other pilots are not directly linked to biomass mobilisation, but rather related to increased resource efficiency (e.g. smart-grid concepts, cascade use of biomass) and forest ecology (e.g. forest biodiversity, soil quality, soil compaction, erosion).

2.4.2.1 Forest soil improvement

Forest soil is very sensible to forest utilization (harvesting, clear cuts, thinnings, etc.). Intensive forest use can lead to a loss of nutrients in the soil, which consequently leads to a reduction of growth (forest increment). In certain cases, especially when forest soil is of very poor quality the return of nutrients with fertilizer is of relevance. The pilot study **SE.1 Skogsbränsle Småland** in Sweden aims to recycle wood ash to provide forest soil with nutrients and to additionally facilitate ash spreading in the forest using adapted machinery. The purpose is to increase customer acceptance of pelletizing the wood ash. An LCA was carried out to compare loose ash spreading and pelletized wood ash spreading in the forest.

In the first (current) scenario, the GHG emissions were 54.7 kg CO_2-eq./ton spread ash. In the second (pilot) scenario they were 43.5 kg CO_2-eq./ ton spread ash. The main impact in loose ash spreading came from the necessary activities for soil preparation and ash spreading (fuel use). In the pilot case, the main impact came from the combined soil preparation and ash spreading process. The impact of the combined process was however less than in the current situation, because only one vehicle was needed. The ash granulation itself was associated to a low impact, because only electricity is needed. The impact from Swedish electricity on GWP is very low, because of the high share of renewable sources for electricity production.

Minor differences result in this specific case from the fact that currently ashes are transported approximately 50 km to be compacted and crushed. It was assumed that pelletising would happen direct at the CHP facility producing the ash. The main differences result therefore from the two steps necessary when loose ash is spread. In addition, transport for the compacting and crushing of ash has an influence on the result. Ash recycling and spreading to forest can lead to an increased tree productivity. Consequently, an additional amount of forest biomass could be harvested.

2.4.2.2 Upgrading of energy carriers

In some cases, the upgrading of the fuel from wood chip to pellets make sense, especially if new business opportunities may be generated. The pilot case of Bruins and Kwast up-graded wood chips from landscape elements to pellets (‘Streekpellets’) to increase consumer acceptance. The sustainability performance is described in the sub-section 2.4.1.2.

In the pilot case **DE.5 Füngeling** in Germany, the idea was to generate a higher value product out of wood wastes from used wooden pallets. A new installation of a pellet production would replace the current wood chips use and allow also to target also industrial clients at regional scale. This concept would foster an initial cascade use of wood resources and increase resource efficiency in the company. However, the pilot study could not be further developed, because strong legal restrictions were identified during the feasibility study (i.e. wood pallets are classified by the regulation as potentially contaminated wood).

2.4.2.3 Optimisation of systems

New energy concepts include the extension of the power range, further reduction of emissions, optimisation of systems and combined systems, annual efficiency improvement and the development of market-ready small-scale and micro CHP systems (Biermayr, 2013).

Pilot studies in the model region of Estonia (**EE.1 Ilmasaare, EE.2 Taarapollu**) focussed on mini and micro CHP plants. No LCA was carried out for pilot studies in Estonia and pilot projects could not be further implemented during the project lifetime, because national grants and investors could not be achieved to support the project's implementation.

Small-scale and micro CHP systems can reduce the risk of incomplete combustion if they use well-defined fuels. According to Lenz and Ortwein (2017), such units can achieve a high electrical efficiency, if solid biomass is gasified in the first step and then converted in an internal process, e.g. by a gas engine or a fuel cell. However, well-defined fuels are needed with reliable composition, low inclination to slagging and appropriate fuel grain sizes are required to achieve an optimal combustion process. If the requirements can be fulfilled, then emissions of CO, NOX or particle matter can be very low and emissions of CH4 and soot are even zero. However, LCA based results on mini and micro CHP plants are still rare, which makes a literature-based quantitative assessment quite difficult.

Smart energy concepts are another examples for optimised systems, which were submitted as a pilot study from **ES.4 Probiomassa**. Although no LCA was conducted for this pilot case, the GHG saving was determined to be 1,004 tons CO_2-eq. for a total of 800 tons mobilised biomass and 15 TJ per year.

Another pilot study **SE.3 Lessebo** in Sweden focused on process optimization. The company installed a flue gas condenser to increase the energy efficiency of their process. No LCA was conducted in this case. However, this pilot case is seen as very positive in environmental terms. The ratio of national increments and fellings in Sweden has already reached 100%. In order to exploit forest resources not any further, the optimization of existing bioenergy processes is favourable. Forest sources are used more efficiently. Additionally, air emissions from the combustion process are also decreased.

3 Certification

This chapter presents the outcomes of WP4 Tasks T4.1 ‘Sustainability standards’, T4.4 ‘Sustainability indicators and criteria’ and T4.5 ‘Sustainability certification’. The progress and results of the trainings, pre-checks and certification of selected pilot project cases are reported.

3.1 Goal and Scope

The basis of a certification scheme is a normative framework. The conformity of a product, system, service, etc. with a standard is evaluated within the certification process. The kind of normative framework depends on the certification scheme and can be national or international standards or other types of basic rules. National or international standards could be DIN, DIN EN or DIN EN ISO or similar national standards from other countries.

In the field of sustainability standards for biomass and bioenergy, the certification basis are usually system documents from different schemes. These system documents are mostly based on a generic structure of principles, criteria and indicators.

3.2 Materials and method

A review of certification standards was conducted on national, EU and international level. Based on the identified standards, the nature of the company and the activities of the company, potential applicable certification schemes on the same levels were identified and matched.

As a second step, the pilot projects were evaluated and clustered according to the certainty and suitability that a certification could be implemented in the company. The clustering for certification had the following three levels: low, medium, high and uncertain. The main factors for the clustering was the structure and processes within the organization. In the pilot regions, the regional partners held several meetings with the SMEs, to inform them about the availability, the benefits of certifications and to check the interest of the SMEs in the regions.

The further focus was taken to pilot projects within the high and medium suitability cluster of certification.

Training seminars were conducted by DIN CERTCO in selected model regions to inform on quality aspects along the supply chain via certification among stakeholders involved in the pilot projects but also beyond the project. Seminars conducted in the following model regions:

- Catalonia, Sept 2016 in Solosona
- Western Macedonia, Jun 2017 in Kastoria
- Southern Estonia
- Ukraine, Nov 2017 in Lviv

The process below was the proven instrument for the approach.

Figure 3.1: Approach of certification trainings

3.3 Sustainability certification of pilot project cases

The region of Catalonia has a high density of producers of solid biomass in from of wood chips and wood pellets. Local company clusters and a high forest density provide evidence that in northern Spain many SMEs are active in the production of wood pellets and wood chips. It was also found that there were already ongoing activities of two national biomass associations to improve the quality of wood pellets through different certification schemes.

One pilot project in Catalonia, Novalia Sinergie, showed high interest in the possibility of certification right from the beginning. The company had a good level of system quality, which the first evaluation and audit showed. The wood pellet standard ISO 17225-2 was fulfilled. After the evaluation of the audit results by the accredited certification body DIN CERTCO, the certification was awarded to Novalia Sinergie.

The second pilot project Sala Forestal aims at logistics centres for wood chips. They already have a PEFC certification, which could be extended in the future to an additional FSC certification. The information package and relevant documentation was provided to the company. However, until now no commitment from the company could be obtained.

The third Spanish company Probiomassa, another pellet plant factory, had also been already certified for wood pellets. They have the certification for PEFC CoC (Chain of Custody).

The companies BAV Bergischer Abfallverband and Regetherm in Germany showed initial interest in marketing of regional wood under a regional certificate. The PEFC Regional Label and the PEFC-CoC label for sustainable forest management might be suitable for these companies. An information package and relevant documentation was provided, and the companies signalled a general interest. Further communication and preparatory steps for certification and the financing are required.

Among the Dutch pilot projects, one company was identified as suitable for certification. The company Ribo develops strategic biomass storage facilities and produces wood chips for the supply to local energy distributers. Even though the company is small, a PEFC certification seems suitable for the company. The regional lead partner has provided the information to the company and further communication is ongoing.

In the other model regions Småland (Sweden), Western Macedonia (Greece) and Southern Estonia, none of the pilot projects communicated a need or interest to engage in certification activities. The reasons can be found in the different market situations of these regions:

- In Sweden, domestic producers comply with the national legislation and certification requirements. International biomass exports are not relevant.
- In Greece, the bioenergy sector is not yet strongly developed. Due to the financial crisis, large investments in new bioenergy capacities are unlikely in the near future.
- In Estonia, an emerging bioenergy market is growing. Domestic producers do not yet require certifications (which can however change once new legislation is in place). Producers and exporters for international markets are often already certified.

Given this market situation, DINCERTCO initiated a number of additional activities to mobilise the market for certification in these regions, and beyond, as explained in the next chapter.

3.4 Market mobilisation activities for certification

3.4.1 Catalonia, Spain

Spain is a fast growing market for wood pellets and wood chips production. The producers in the region are medium and small companies. It is evident that especially the raw material preparation, the production and the supply chain of solid biofuels needs to have an systematic quality approach and should comply with common standard requirements.

The best way to implement a systematic quality approach is to comply with standards and systems, which assure that the standards are implemented in the companies or in the processes within the company, and also in the logistic supply system. To assure that standards are implemented, the best verification indicator is a suitable certification.

Sustainable biofuels are becoming more and more relevant in decentral heating and energy supply grids in the region. Especially solid biofuels can show a preferable global warming potential and are more efficient in comparison to fossil fuels if the supply chain and product quality reach a high level.

Therefore, the SecureChain partners CTFC, DIN CERTCO and BTG decided to undertake further efforts to mobilise the Spanish market and encourage more companies to participate in the SecureChain certification support program. Within the secure chain project already several companies were attracted by the secure chain voucher, roadshows and learning labs. To reach more companies the secure chain partners decided to conduct a seminar with the focus of pellet manufacture.

Approach to reach the market: DIN CERTCO and CTFC undertook a market survey of local solid biomass manufactures. 60 manufacture were identified.

Market mobilisation by the training seminar: A training seminar for Quality Managers of production of solid biofuels / wood pellets was developed by experts from DINCERTCO, TÜV Rheinland and CTFC, as an effective means to bring expertise and knowledge to the manufactures. Also local experts from Catalan communities were involved. The seminar was held at the premises of CTFC in Solsona, Spain on the 16th September 2016 (see D6.2 documentation). The following topics were addressed:

- QM-System implementation based on the DINplus certification scheme:
  a) In Process, b) Requirements storage, c) Quality testing laboratory
- Wood Pellets - Quality Assurance during Transportation and
- Warehouse Logistics according to ÖNORM M 7136
- Quality requirements of Wood pellets and briquettes according DIN EN ISO 17225-2, DIN EN ISO 17225-3
- Requirements of the EU-Timber regulation
- Introduction of the requirements of PEFC/ FSC

Attendance of the Seminar: Eventually 30 companies from different parts of Spain participated in the training. Major attendance were pellet factories and forest companies. The Spanish Biomass Association Appropellets was present as speaker.

Outcomes of the Seminar: Several market actors could be reached. The Feedback was very positive, 17 filled in the feedback form. Out of the total 30 participants, 3 companies were interested in certification. 6 companies confirmed that the presented topic covered the expectations and stated that they received from seminar the necessary knowledge for their business activities. Table 4.3 shows that certification is a interesting topic for the audience.

Table 3.1: Training Feedback Spain

Certification scheme	***Number of interested participants***
DIN*plus* certification of wood pellets	17 participants
DIN*plus* certification of wood briquettes	5 participants
FSC or PEFC	11 participants
Sustainable Biomass Partnership (SBP)	7 participants
Qualified Enterprises of Pellet Logistics	8 participant

Further future cooperation with the Spanish pellet association Appropellets was agreed with DINCERTCO. At the Aragon Fair Feb. 2017 (Spain-Zaragaoza), CTFC put a stand with Apropellets (Spanish Pellet Association).

After the seminar visited DIN CERTCO one pellet manufacture. DIN CERTCO conducted a gap analysis in form of an audit prior the certification according to the certification scheme of wood pellets for use in small furnaces in accordance with DIN EN ISO 17225-2 (A1). During the audit several non-conformities were identified which has to be corrected before the final evaluation and the certification takes place.

The audited company will be engaged to correct their non-conformities until the third quarter of the year and will than face the certification process.

CTFC became also recognized as a Testing Laboratory and Inspection Body to conduct the preliminary required testing for certification of wood pellets quality. CTFC also conducts the required inspections to assure quality in the factories production process.

3.4.2 Estonia

The SecureChain partners DINCERTCO and TREA (Tartu Regional Energy Agency) organized a successful training seminar about certification in Tartu, Estonia.

The total number of participants of the training were 30 companies from different parts of Estonia. Major attendants were pellet factories and forest companies. Also the local Estonian Biomass Association and Foundation Private Forest Centre in Estonia were invited as speakers.

Table 3.2: Training Feedback Estonia

Certification	**Number of interested participants**
DIN*plus* certification of wood pellets	3 participants
FSC or PEFC	3 participants
Sustainable Biomass Partnership (SBP)	7 participants
Qualified Enterprises of Pellet Logistics	2 participant

The feedback was very positive. 13 participants out of 30 filled the feedback form. 12 companies confirmed that the presented topic covered the expectations and even 13 participants stated that they received from seminar the necessary knowledge for their business activities. Table 4.4 shows that certification is a very interesting topic.

However, the participants stated that the following topics of wood in energy could further enrich trainings / seminars in the future.

- Burning of waste wood and old wood (timber, furniture etc.)
- Gasification of wood and technology

- Wood based fuels for transport
- Algae biomass fuels and technology
- Experiences of small scale biofuel producers, examples
- Certification – how to implement standards (regulations, methodology, documentation)
- Updates of Renewable energy directive

3.4.3 Western Macedonia, Greece

A full day training was conducted on 29 June 2017 in Kastoria, hosted by the partner CLUBE (Cluster of Bioenergy and Environment in Western Macedonia), to train the trainers and consultants. It became clear that local SecureChain partners need deeper knowledge of the identified certifications to further inform and identify the market actors about the potential of certification in the area of solid biofuels. CLUBE invited numerous local companies from Greece to benefit from the seminar. In total 44 persons participated. The seminar included also additional topics to cover a broader range of industries. The main topics were:

- Wood Pellets - Quality Assurance during Transportation and Warehouse Logistics according to ÖNORM M 7136
- Quality requirements of Wood pellets and briquettes according DIN EN ISO 17225-2, DIN EN ISO 17225-3
- Requirements of the EU-Timber regulation
- Introduction of the requirements of PEFC/ FSC The systems for sustainable and environmentally friendly management of forests
- Introduction to the ISCC - Sustainable Biomass Consideration of the complete value chain from the farmers to the trader of biofuels/biomaterials and assures traceability within this value chain « Introduction of ISCC PLUS which enables to proof sustainability in non-regulated markets like food or feed as well as technical/chemical applications.
- Introduction to the Redcert - Sustainable Biomass- requirements in the bioenergy market and requirements in the supply chains of the food and feed market

3.4.4 Carpathian Region, Ukraine

The SecureChain partner ESS in Sweden obtained an additional grant from the Swedish Institute (SI) for a bilateral project with Eastern European countries. This project SECVALCHAIN is a complementary action to SecureChain, which aims to introduce the Carpathian Region of Ukraine, a forest-rich region in the neighborhood of Europe, to this European collaboration project. The local partner is the Ukrainian NGO organization FORZA (Agency for Sustainable

Development of the Carpathian Region). With the additional grant from SI, comparable actions in line with the SecureChain project can be carried out in Ukraine.

Ukraine is an important emerging market for bioenergy and already today a major producer of solid biofuels for export to the EU. With the additional grant from SI, comparable actions in line with the SecureChain project can be carried out in Ukraine. Ukraine is an important emerging market for bioenergy and already today a major producer of solid biofuels for export to the EU. As foreseen DINCERTCO and FORZA organized joint trainings on pellet quality assurance in the production process and product certification of wood pellets in Ukraine. Also here we could experience a high interest of the local manufacture for the seminar carried out in November 2017 in Leviv. It was an open discussion and many answered questions gave the audience ideas how to improve quality of their production process via certification.

4 Review and lessons learnt

SecureChain's pilot projects lead to additional mobilised biomass mainly from regional sources, which reached a total volume of mind. 77,000 tons. Sustainability of the pilot projects was assessed first of all by means of Life Cycle Assessment to detect environmental hot spots and to generate lifecycle GHG emissions along the supply chain from primary data. The LCA helped to understand specific research questions and its effects on the environmental performance (in this case on the GHG emission performance). Primary data from pilot projects was of sufficient quality and good cooperation and communication during data collection enhanced the quality of the study.

Besides the LCA a sustainability assessment was carried out with respect to environmental impacts other than climate change as well as social and economic impacts. All pilot projects achieved in general a sustainable performance and saved mind. 42,000 tons CO_2-eq and 50,000 tons CO_2-eq on average compared to fossil energy. Relevant sustainability indicators were addressed for all pilot projects in the most objective way, which means that both positive but also negative aspects on the performance were highlighted in the context of each pilot case. A regional job creation potential of approx. 58 FTE was achieved by the pilot projects. The determination of the job creation potential along the entire supply chain (forest to consumer) was possible for some pilots and it resulted in 113 FTE. In comparison to that, a fossil supply chains would only lead to 22 FTE on regional jobs (see Table 6.7).

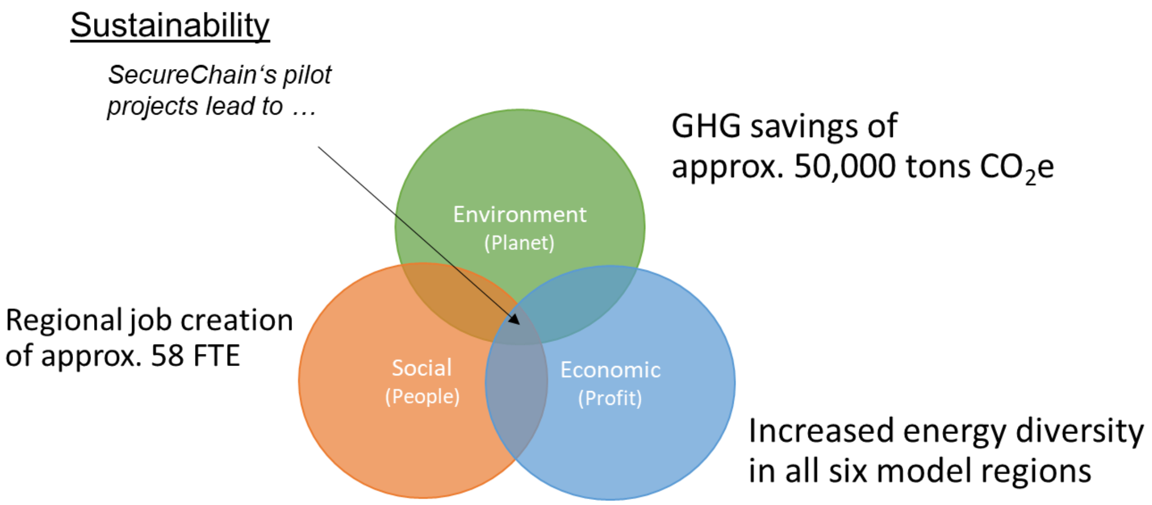

Figure 4.1: Sustainability check of SecureChain

Restrictions of the sustainability assessment were experienced in terms of time and applicability. For some sustainability criteria, which were identified as relevant, data describing the criteria was lacking or the expertise or the method to assess the criteria was not apparent. Furthermore, pilot cases are very different with respect to the context. They represented one or even more steps of the entire bioenergy chain (e.g. fuel supply, fuel production) and for different types of solid biomass (e.g. forest residues, saw dust, residues from landscape elements, short rotation coppice) and energy carriers (e.g. pellets, wood chips) so that it was challenging to focus on one set of sustainability criteria. Some criteria is applicable for a pilot case but some are not. For example, are other criteria in focus when energy crops are assessed or forest residues. In the same time, objectivity and homogeneity had to be ensured during the assessment to not oversee some significant impacts. Another difficulty when applying sustainability criteria for pilot cases is to compare pilots which are in the end not comparable because of different contexts. This report highlights important sustainability aspects and contributes success stories and good practices to enable a low carbon economy in Europe.

Furthermore, certification served as an integral tool to increase market acceptance and consequently to promote bioenergy in the regions. Certification trainings and seminars which were conducted during the project led to cooperation at regional level and to a spreading of information to interested parties. Seminars during the project were the starting point of a broader outreach to stakeholders beyond the project regions, notably in Ukraine and Portugal.

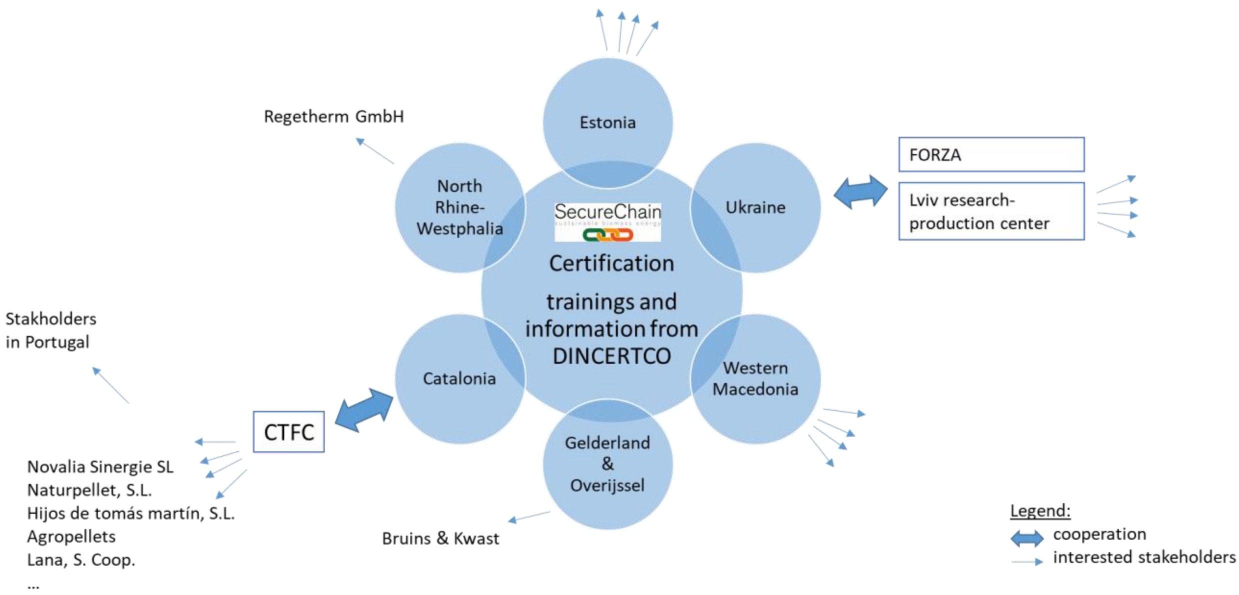

Figure 4.2: Effect of certification trainings and advice within SecureChain

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6 ANNEX

6.1 Project activities

Sustainability was part of work package (WP) 4 of the project SecureChain with the following objectives:

- Supervise the implementation of sustainability monitoring schemes of high standard and enhanced transferability in local supply chains.
- Perform in-depth Life Cycle Assessment (LCA) of proposed SSCM pilot projects in view of direct and indirect environmental impacts and energy balances
- Prepare and guide supply chain members towards successful sustainability certification.

WP4 was split into the following sub-tasks:

- T4.1 Sustainability standards and pre-check
- T 4.2 Sustainability pre-check
- T 4.3 LCA performance check
- T4.4 Sustainability criteria and indicators
- T4.5 Sustainability certification

6.1.1 Distribution of work

Work package leader is BOKU who was in charge of the LCA and sustainability pre-check, criteria and indicators. DIN CERTCO was in charge of the sustainability certification. Support for the Life Cycle Assessment was provided by each regional lead partner and for one case study in Western Macedonia by CPERI in data collection and interpretation. Contributions to the final report were furthermore provided by the Catalonian partner CTFC. The review of all deliverables was conducted by the project coordinators.

6.1.2 Description of work

T4.1 and T4.2 were conducted in period 1 of the project and are not described here.

T 4.3 LCA performance check

Period 1 of the project focused on the determination of research questions and system boundaries for the life cycle assessment. In period 2 data was collected for the assessment and the life cycle impact assessment was conducted for several case studies.

For the sustainability assessment, several steps were taken to collect information in an efficient way. The literature research conducted for the first progress report D4.1 (Obersteiner et al., 2016) served as a basis to identify the most crucial aspects of sustainability in the field of bioenergy and its implementation in the SecureChain pilots. The next step was to collect data for the Life Cycle Inventory (LCI) to assess pilots, which chose to be accompanied by a Life Cycle Assessment (LCA). Data collection guidelines and sheets (see Annex of D4.1) were distributed among the companies via Regional Lead Partners (RLP). The collected data were screened and tested for their completeness and plausibility. Open questions were sent to companies and the data were adapted. The information exchange was carried out primarily via the pilot partners directly or via the regional lead partners. This process demanded several turns until the LCI was sufficient complete to conduct the LCA. Especially on-site visits (Western Macedonia in July 2016, North Rhine Westphalia in October 2016) and participation at Learning Labs (Catalonia in March 2016) supported the process significantly, as it is sometimes difficult to explain LCA issues in different languages. The Austrian benchmarking tour, which was carried out in March 2017, also included a session where pilot partners discussed in small groups the LCI and LCA of their pilot projects, which significantly put forward the progress of conducting the LCA.

Finally, eight LCAs were conducted. The rest of the pilot cases had no interest or were still in a theoretical phase of implementation. In each model region, at least one LCA was carried out except for the region of Southern Estonia. Attempts were conducted to assess the case of Taarapollu. Research question and system boundaries were exchanged with the regional lead partner. However, the impact assessment couldn't be finalized due to a lack of data. Life Cycle Inventory and Life Cycle Impact Assessment are described in detail in the unpublished Deliverable 4.2 (Obersteiner et al., 2017). The Life cycle interpretation and the LCA results are shown with other sustainability criteria are furthermore described, in the published Deliverable 4.3. Goal and scope, system boundaries and scenarios are described without detailed Inventory data (out of confidentially reasons) for each pilot case in the annex of D4.3 to ensure transparency and reproducibility.

Table 6.1: Pilot cases and conducted LCAs

Model region	Pilots	Type of assessment
Småland	Värnamo	LCA literature based
Småland	Skogsbränsle Småland	LCA
Gelderland & Overijssel	Hissink&Zonen	LCA literature based
Gelderland & Overijssel	Ribo Holding	No LCA, Default values used to calculate GHG
Gelderland & Overijssel	Bruins & Kwast	LCA
Catalonia	Sala Forestal	GHG calculations
Catalonia	Novalia	LCA
Catalonia	La Fageda	No LCA, Default values used to calculate GHG
Catalonia	Probiomassa	No LCA, Default values used to calculate GHG
Southern Estonia	Ilmasaare, Taarapollu, Starfeld	No assessment
Germany	AVEA	LCA
Germany	Regetherm/Füngeling	No assessment
Western Macedonia	Alfa Wood	LCA
Western Macedonia	AZ Bioenergia	LCA
GR	Matesion	No LCA, Default values used to calculate GHG

T4.4 Sustainability criteria and indicators

A condensed documentation of suitable criteria and indicators is supplied in Obersteiner et al. (2018). Sustainability criteria and indicators were collected from a range of European reports (European Commission, 2010b, 2014a, 2017; Giuntoli et al., 2015) and standards (FAO, 2011; Forest Europe, 2015; World Energy Council, 2017). In total 61 impact categories (23 environmental, 19 social and 19 economic) and according 71 indicators have been considered for the further examination. The categorized list of impact categories out of the literature review was examined by a panel consisting of experts and practitioners from the model regions involved in the pilot cases. A judgement of each impact category was conducted according to its feasibility in terms of data availability and accessibility as well as its relevance with regard to the pilot cases. The reasoning behind the judgement had to be stated by each expert. Selected criteria are the following:

Table 6.2: Selected sustainability criteria

Sustainability criteria	Implementation approach	Data source
Sustainability dimension: Environment		
Harvest levels of wood resources	quantitative: ratio net annual increment and annual fellings of wood on forest available for wood supply	National level data from Eurostat 2015b
Resource efficiency	qualitative: Type of biomass	European Commission (2007)
Lifecycle GHG	quantitative: GHG emission savings per final energy commodity by LCA method	Primary data from SMEs
	quantitative: Global Warming Potential by LCA method to draw recommendations for SMEs	Primary data from SMEs
Soil quality	qualitative for case studies affected by the criteria	Qualitative information from SMEs
Air quality		
Biodiversity		
Water use and efficiency	qualitative for case studies affected by the criteria (Energy crop case studies)	Qualitative information from SMEs
Water quality		
Land use change		
Indirect land use change		
Sustainability dimension: Social		
Workforce	quantitative: Ratio total number of job along the value chain of the pilot study to reference energy scenario	Primary data and Höher et al. (2015)
Social-political acceptance	qualitative: acceptance among public, stakeholders, policy makers	Qualitative information from regional lead partner
Market acceptance	qualitative: ready for market uptake	
community acceptance	qualitative: acceptance among local community	
Sustainability dimension: Economic		
Energy efficiency	Quantitative: Ratio energy to total biomass yield	Primary data from SMEs
Energy diversity	semi-qualitative with Eurostat data	National level data from Eurostat 2016

To deepen discussion on sustainability and LCA in the area of bioenergy and further to disseminate project activities and results in the LCA community, two international conferences were visited. A poster was presented at the 8th International Conference on Life Cycle Management, 3rd to 6th September, 2017, Luxembourg and an oral presentation was conducted at the 5th Central European Biomass Conference, 18th - 20th January 2017 in Graz, Austria:

- Scherhaufer, S.; Obersteiner, G.; Fallas, Y.; Arranz-Piera, P.; Gustavsson, G.; Kies, U. (2017): Environmental benefits from regional bioenergy value chains. Proceedings of the 5th Central European Biomass Conference, 18th - 20th January 2017 in Graz, Austria, Austrian Biomass Association. ISBN 978-3-9504380-1-7, Abstract, p. 112.

- Scherhaufer, S.; Obersteiner, G.; Fallas, Y.; Arranz-Piera, P.; Horta, F.; Gustavsson, G.; Kies, U. (2017): Environmental assessment of bioenergy on the example of pilot projects using solid biomass, Poster at the 8th International Conference on Life Cycle Management, 3rd to 6th September, 2017, Luxembourg

T4.5 Sustainability certification

Training seminars were conducted by DIN CERTCO in the model regions to inform on quality aspects along the supply chain via certification. Seminars conducted in the following model regions:

- Catalonia, Sept 2016 in Solosona
- Western Macedonia, Jun 2017 in Kastoria
- Southern Estonia
- Ukraine, Nov 2017 in Leviv

In the region Catalonia two fairs, Aragon Fair Feb. 2017 (Spain-Zaragaoza), and Expobiomassa Valladolid (Setember-October 2017), were additionally visited by CTFC, a cooperation partner of DIN CERTCO in the region, to inform stakeholders about the project and about certification. In the latter fair CTFC had a stand with Apropellets (Spanish Pellet Association).

Furthermore, one pellet manufacturer in Catalonia could be visited by DIN CERTCO. DIN CERTCO conducted a gap analysis in form of an audit prior the certification according to the certification scheme of Wood pellets for use in small furnaces in accordance with DIN EN ISO 17225-2 (A1). During the audit several non-conformities were identified which has to be corrected before the final evaluation and the certification takes place.

The main interest of the stakeholders was the combination of pellet quality assurance with sustainability aspects in form of PEFC (The Programme for the Endorsement of Forest Certification Schemes) and FSC certification (Forest Stewardship Council). Stakeholders within the project but also beyond the project visited the seminars and showed a high interest of stakeholders in certification. Certification was identified as an important tool for market mobilisation. Activities with the project SecureChain resulted in effects also beyond the project in the various regions, which is good success and fosters quality assurance through increased certification.

6.2 Quantification of Life cycle based GHG emissions

6.2.1 Method

Life cycle GHG emissions

The most prominent criteria is the life cycle based greenhouse gas (GHG) indicator. The GHG indicator is expressed as the reduction of GHG emissions of a bio-based fuel chain in comparison with a fossil-based fuel chain (Bergsma et al., 2006; Guinée et al., 2009). GHG emission savings from the use of biofuels and bioliquids shall be at least 35% in comparison to a fossil reference system, increasing to 60% until 2018 according to Article 17(2) of the Renewable Energy Directive.

The GHG indicator was calculated as follows:

Formula 1:

$$\text{GHG reduction} = \frac{\text{GHG emission, fossil chain} - \text{GHG emission, bio-chain}}{\text{GHG emission, fossil chain}}$$

(Bergsma et al., 2006; Guinée et al., 2009)

However, the methodological considerations need to be consistent throughout an evaluation to ensure comparability among systems. Guinée et al. (2009) highlighted that the GHG indicator is highly sensitive for different choices such as the handling of biogenic CO_2 and the treatment of coproducts and recycling. If the substitution approach is used, then the results are also highly dependent on such choices as what process or system would be substituted, e.g. bioenergy substitute coal, oil or gas based energy.

6.2.2 Data inventory

Table 6.3: Default values on GHG emissions in the bioenergy sector

Default values based on (Giuntoli et al., 2015)			
GHG emissions			
wood chips:	6	g CO_2 eq./MJ	from forest residues, transport distance 1 to 500 km
	6	g CO_2 eq./MJ	from stem wood, transport distance 1 to 500 km
pellets:	7	g CO_2 eq./MJ	from forest-residues, pre-dried wood chips is used to provide process heat
	22	g CO_2 eq./MJ	from wood industry residues, natural gas boiler is used to provide process heat
natural gas:	71.7	g CO_2 eq./MJ	
diesel:	93.9	g CO_2 eq./MJ	

biogas for electricity from wet manure	12	g CO_2 eq./MJ	electricity required in the process from the grid, process heat is supplied by the CHP engine itself (Case 2)
LHV			
wet wood chips	12.60	MJ/kg	
wood pellets (wet)	16.9	MJ/kg	
Fossil fuel comparator (SWD(2014)259)			
heat	80	g CO_2 eq./MJth	
electricity	186	g CO_2 eq./Mjel	
natural gas	72	g CO_2 eq./MJng	
Oil-fired boiler	92	g CO_2 eq./MJ	

6.2.3 Cumulative results

Cumulative results of different scenarios investigated in the pilot specific LCA's, LCA results as well as results based on default values of Giuntoli et al. (2015) and European Commission (2014).

Table 6.4: Cumulative results of GHG emissions and savings (minimum values)

Data source	*Scenario*	*Company*	*additional mobilised biomass (tons) (quantity in pilot - quantity in status quo)*	*additional heat (MJ)*	*additional electricity (MJ)*	*Reference system*	*GHG emission fossil (tons CO_2.eq.)*	*GHG emission bio (tons CO_2.eq.)*	*GHG savings (%)*	*GHG savings (tons CO_2-eq.)*
Default values	**ES.1 (consequ.)**	**Sala Forestal**	**8700**	**98,658,000.00**		**Fossil fuel comparator**	**7,892.64**	**591.95**	**93%**	**7,300.69**
Default values	ES.2 (consequ.)	La Fageda	750	8,505,000.00		natural gas and gas oil	543.62	51.03	91%	492.59
Default values	ES.2 (default)	**La Fageda**	**750.00**	**8,505,000.00**		**Fossil fuel comparator**	**680.40**	**51.03**	**93%**	**629.37**
SecureChain	ES.3 (status quo)	**Novalia**	**45000**	**846,450,000.00**		**Fossil fuel comparator**	**67,716.00**	**52,489.92**	**22%**	**15,226.08**
SecureChain	ES.3 (scen A)	Novalia	45000	846,450,000.00		Fossil fuel comparator	67,716.00	42,723.19	37%	24,992.81
SecureChain	ES.3 (scen B)	Novalia	45000	846,450,000.00		Fossil fuel comparator	67,716.00	10,267.59	85%	57,448.41
Default values	ES.3 (default)	Novalia					67,716.00	18,621.90	73%	157,439.70
SecureChain	SE.1 (consequ.)	Skogsbränsle		180,000,000.00		Fossil fuel comparator	14400	1,080.00	93%	13,320.00
Default values	SE.2 pellets default	Värnamo		42,000,000.00		Fossil fuel comparator	3,360.00	294.00	91%	3,066.00
SecureChain	**SE.2 pellets LCA review**	**Värnamo**				**Fossil fuel comparator**	**3,360.00**	**140.70**	**96%**	**3,219.30**
SecureChain	SE.2 pellets LCA review	Värnamo		42,000,000.00		Oil fired boiler	3,864.00	140.70	96%	3,723.30
Default values	SE.2 chips default	Värnamo		42,000,000.00		Fossil fuel comparator	3,360.00	252.00	93%	3,108.00

Data source	*Scenario*	*Company*	*additional mobilised biomass (tons) (quantity in pilot - quantity in status quo)*	*additional heat (MJ)*	*additional electricity (MJ)*	*Reference system*	*GHG emission fossil (tons CO_2.eq.)*	*GHG emission bio (tons CO_2.eq.)*	*GHG savings (%)*	*GHG savings (tons CO_2-eq.)*
SecureChain	**SE.2 chips LCA review**	**Värnamo**				**Fossil fuel comparator**	**3,360.00**	**136.50**	**96%**	**3,223.50**
SecureChain	SE.2 chips LCA review	Värnamo		42,000,000.00		Oil fired boiler	3,864.00	136.50	96%	3,727.50
SecureChain	EL.1 (min. yield)	AZ Bioenergia		54,950.40	30,909.60	Electrcitiy mix and heat from lignite	6.69	12.45	-86%	- 5.76
SecureChain	EL.1 (med. yield)	AZ Bioenergia		54,950.40	30,909.60	Electrcitiy mix and heat from lignite	6.69	7.15	-7%	- 0.46
SecureChain	EL.1 (max.)	AZ Bioenergia		54,950.40	30,909.60	Electrcitiy mix and heat from lignite	6.69	1.84	72%	4.85
Default values	EL.1 (minimum yield)	AZ Bioenergia		54,950.40	30,909.60	Fossil fuel comparator	10.15	12.45	-23%	- 2.30
Default values	EL.1 (medium yield scen)	AZ Bioenergia		54,950.40	30,909.60	Fossil fuel comparator	10.15	7.15	30%	3.00
Default values	**EL.1 (maximum yield)**	**AZ Bioenergia**		**54,950.40**	**30,909.60**	**Fossil fuel comparator**	**10.15**	**1.84**	**82%**	**8.30**
Default values	EL.1 (default)	AZ Bioenergia		54,950.40	30,909.60	Fossil fuel comparator	10.15	2.23	78%	7.91
SecureChain	EL.2 (status quo)	Alfa wood		12,076,875.00		Heavy fuel oil	1,014.08	121.50	88%	892.58
SecureChain	**EL.2 (90:10)**	**Alfa wood**		**12,076,875.00**		**Heavy fuel oil**	**1,014.08**	**102.28**	**90%**	**911.80**
SecureChain	EL.2 (100:0)	Alfa wood		12,076,875.00		Heavy fuel oil	1,014.08	82.61	92%	931.46
SecureChain	EL.2 (0:100)	Alfa wood		12,076,875.00		Heavy fuel oil	1,014.08	260.95	74%	753.12
Default values	EL.2 (default)	Alfa wood		12,076,875.00		Fossil fuel comparator	966.15	72.46	93%	893.69
Default values	**EL.3 (default)**	**Matesion**		**371,250.00**	**288,750.00**	**Fossil fuel comparator**	**83.408**	**7.920**	**91%**	**75.488**
SecureChain	DE.3 (pilot)	**AVEA**	**686**	**5,735,389.71**	**3,184,010.29**	**Fossil fuel comparator**	**1,051.06**	**0.00176**	**100%**	**1,051.06**

Data source	*Scenario*	*Company*	*additional mobilised biomass (tons) (quantity in pilot - quantity in status quo)*	*additional heat (MJ)*	*additional electricity (MJ)*	*Reference system*	*GHG emission fossil (tons CO_2.eq.)*	*GHG emission bio (tons CO_2.eq.)*	*GHG savings (%)*	*GHG savings (tons CO_2-eq.)*
Default values	NL.2	**Ribo Holding**	**200**	**1,620,000.00**		**Fossil fuel comparator**	**129.60**	**9.72**	**93%**	**119.88**
Default values	NL.3	Bruins & Kwast	15636	159000000		Fossil fuel comparator	12,720.00	1,113.00	91%	11,607.00
SecureChain	NL.3	**Bruins & Kwast**	**15636**	**159000000**		**Fossil fuel comparator**	**12,720.00**	**757.14**	**94%**	**11,962.86**
Default values	ES.4	**Probiomassa**	**800.00**	**15,048,000.00**		**Fossil fuel comparator**	**1,203.84**	**105.34**	**91%**	**1,098.50**
TOTAL GHG emission savings									**41,603.33**	

6.3 Quantification of job creation

6.3.1 Goal and scope

To quantify the social dimension of sustainability. In this case it is job creation potential.

Job employment in the bioenergy sector increases regional added value and increases also the purchasing power in the region which is reflected in the economic indicator for 'regional added value'.

6.3.2 Method

A large difference between bioenergy and fossil energy exists with respect to the local supply and employment chain. From forest maintenance to transport, production of logs to wood chips until the boiler, the supply chain and employment chain in bioenergy remains all in all a local chain (Höher et al., 2015). To quantify the working hours involved in bioenergy, different steps from the forest to the supply of heat or electricity needs to be accounted for. The working hours are mainly depending on the type of wood provision (motor-manual or mechanical) and the installed heating systems (different maintenance and infrastructure).

The quantification of the job creation indicator in this study is based on working hours from Höher et al. (2015). Höher et al. (2015) used data from the top-down (statistical data) in combination with data from the bottom-up (company data or research for intensity of labour) and generated results for the labour intensity per step of the supply chain. Working hours are given for the steps: Forest management, thinning/final cutting, machinery and maintenance of machinery, transport from forest road to sawmills (Empty truck rides, loading and unloading, transport itself and waiting time is included), sawmilling, infrastructure and operation of biomass heating plant, local biomass logistic centre, fuel trade and infrastructure, maintenance and operation of boilers at consumer level. Although the results of Höher et al. (2015) are based on Austrian data, the working hours are though comparable with working hours of other European Member States. Influencing parameters, such as degree of mechanisation, topography of forest area for wood supply (mountainous or flat area) are adjusted for each case study.

Wood as a resource is used in several wood-based sectors, such as manufacturing of wood and wood products, manufacturing of pulp, paper and paper products and manufacturing of furniture. An allocation of the effort of wood supply as a fuel is therefore necessary. Höher et al. (2015) used the allocation by mass and energy content.

For the indicator the working hours of the bioenergy supply chain are reduced by working hours of the fossil supply chain. For the fossil supply chain only the efforts at fuel trade and consumer level are accounted (Höher et al., 2015). Also the transport of fossil fuels is happening mostly outside of the local area (Höher et al., 2015).

6.3.3 Data inventory

The following parameters to quantify working hours and thereby the job creation potential was identified by Höher et al. (2015):

- **Forest management**, including planting, clearing, protection measures against damage by wildlife or pest insects. 80% of Austrian forest belongs to private owners. Data are based on labour of small and middle forest owners. The effort of forest management is assumed to be constant over several decades until the felling of the trees.

- **Thinning/Final cutting**, including wood transport to the forest road. The working hours can vary strongly depending on the degree of mechanisation and the organisation of work. A major importance in the study highlights the manual felling of trees by chainsaw (so-called motor-manual harvesting). Working hours of the forest ranger to mark trees for felling are included, as well as hours for the maintenance of harvesting equipment, and for cutting off the branches (preparing the raw timber for transport). Values for the different techniques can be found in Höher et al. (2015) p. 63.

- **Machinery and maintenance of machinery**: The topography of a forest area or a country is a crucial factor for the possibilities to use machinery. In Austria, a mountainous country, only 25% of the annual wood harvest volume can be harvested mechanically, whereas in Scandinavian countries circa 80% can be harvested and processed mechanically. The time effort for the maintenance of machinery was estimated on the basis of expert opinions about costs and wage rates.

- **Transport**: Round wood with bark is transported from the forest road usually to sawmills. The means and the distance of transport is again depending on the topography. Empty truck rides, loading and unloading, transport itself and waiting time is included. In contrast, the transport of fossil fuels is happening mostly outside of the local area.

- **Sawmilling**: Sawmill industries comprise a number of processing steps. Employment statistics in this industry were used to calculate the working hours (top-down). A comparison with data obtained in a bottom-up survey of several smaller sawmills was carried out. The results were allocated to the products of the sawmill that are used for energy production.

- **Biomass heating plant**: The building of the infrastructure of a plant can only be estimated from the building costs. It results in 4 full time equivalents per MW installed. The operation of a plant includes maintenance of the boiler, cleaning, intake of wood and small repairs. Additionally, administrative work needs to be included (approx. 25% more).

- **Local biomass logistic centres** are hubs where wood as a fuel is produced, stored and sold, operated by farmers or foresters. The labour intensity of this logistic centres can be determined by adding the values from the up-stream processes.

- **Fuel trade and consumer**: At consumer level, employment needs to be considered for building the infrastructure, maintenance and operation of the boiler or stove.

Table 6.5: Results of labour intensity per step of the chain from Höher et al. (2015)

Step of the chain	Working hours per TJ and year
forest maintenance, site tending, site development	16.4
thinning, final cutting	52.3
maintenance of machinery	0.5
local transport of wood	15.5
sawmill (wood chips/log wood production)	94.2
local biomass logistic plant	118.3
biomass heating plant, infrastructure	not adjustible
biomass heating plant, operation	47.1
consumer, pellet boiler incl. fuel trading (excl. local pellet production)	37.6
consumer, oil-fired boiler	21.2
consumer, gas-fired boiler	10.2
consumer, tiled stove	74.6
consumer, stove	33.7
consumer, log wood boiler	24.5
consumer, wood chip boiler	17.6
local biomass heating supply	2.9

The labour impact of the forestry and wood sector in the EU varies among countries, as Eurostat (2015a) shows. It ranges from a maximum of 11.6 AWUs[3] per 1,000 ha in Romania to less than 2 AWUs per 1,000 ha in France and Finland. This according to Eurostat (2015) can be partly explained by different topographies (mountainous vs. lowland), which determine the differences in required labour input (Eurostat, 2015a).

[3] AWU: One **annual work unit**, abbreviated as **AWU**, corresponds to the work performed by one person who is occupied on an agricultural holding on a full-time basis. Full-time means the minimum hours required by the relevant national provisions governing contracts of employment. If the national provisions do not indicate the number of hours, then 1 800 hours are taken to be the minimum annual working hours: equivalent to 225 working days of eight hours each.

Table 6.6: Average working times in EU countries in 2016 (Statista 2018)

Countries	Average weekly working hours	Average yearly working hours
Greece	42.3	2199.6
Estonia	38.4	1996.8
Spain	37.7	1960.4
Sweden	36.4	1892.8
Germany	35.1	1825.2
Netherlands	30.3	1575.6

6.3.4 Cumulative results

Table 6.7: Cumulative results of job creation potential

		Assumptions	*Default from Höher et al., 2015 in h/TJ*	*Novalia*	*Novalia*	*Bruins an Kwast*	*bioenergia*	*Pindos*	*Sala Forestal*	*La Fageda*	*Värnamo (pellets)*	*Värnamo (wood chips)*
	Allocation factor			0.13	0.48			0.48	0.48		0.48	0.48
	Total TJ			846.45	846.45	159.00	0.09	12.08	98.66	8.51	63.72	63.72
Bioenergy chain (in h/ TJ and year)	Forest management	efforts are assumed to be constant over several decades and in all countries	16.4	1804.63	6663.25			95.07	776.64	0.00	501.60	501.60
	Thinning/Final cutting (chipping is included)	low degree of mechanisation (motor-manueal harvesting)	52.3	5755.01	21249.28			303.18	2476.71	0.00	1599.63	1599.63
	Machinery and maintenance of machinery	0.5	55.02	203.15			2.90	23.68	0.00	15.29	15.29	
	Transport	from forest road to saw mill	15.5	1705.60	6297.59			89.85	734.02	0.00	474.08	474.08
	Sawmilling (wood chips/log wood production)	94.2	10365.63	38273.08			546.07	4460.92	0.00	2881.16	2881.16	
	Job creation at pilot	SMART Indicator in FTE/year * FTE per country	3920.80	3920.80	3151.20	137.48	1099.80	78416.00	3920.80	0.00	0.00	
	Local biomass logisitc centres	118.3				10.16	1428.69					
	Biomass heating plant, operation	47.1				4.04	568.82					
	Local biomass heating supply	2.9				0.25	35.02					

		Assumptions	*Default from Höher et al., 2015 in h/TJ*	*Novalia*	*Novalia*	*Bruins an Kwast*	*bioenergia*	*Pindos*	*Sala Forestal*	*La Fageda*	*Värnamo (pellets)*	*Värnamo (wood chips)*
	Fuel trade and consumer	pellet boiler	37.6	31826.52	31826.52	5978.40					1150.02	
		tiled stove	74.6									
		log wood boiler	24.5									
		wood chip boiler	17.6						833.46	149.69		538.31
	total (h)			55433.21	108433.67	9129.60	151.93	4169.40	87721.42	4070.49	6621.78	6010.07
	total (FTE)			28.28	55.31	5.79	0.07	1.90	44.75	2.08	3.50	3.18
Fossil fuel comparator (in h/TJ and year)	oil-fired boiler	21.2	17944.74	17944.74		1.82	256.03	2091.55	64.91	1350.86	1350.86	
		gas-fired boiler	10.2			1621.80				36.44		
	total (FTE)			9.15	9.15	1.03	0.00	0.12	1.07	0.05	0.71	0.71

6.4 LCA results of pilot cases

The scope of each LCA including the results and major outcomes are summarized in the following tables. For the sake of completeness the GHG saving potential based on default values of Giuntoli et al. (2015) is also shown below the LCA results.

6.4.1 Goal and scope of the LCA

The calculation of the Life cycle based GHG emissions follows the principles of ISO 14040 and ISO 14044. Life Cycle Assessment (LCA) offers the most comprehensive method to quantify environmental impacts (including the carbon footprint) over a whole product life cycle. For each pilot case an own LCA was conducted.

Goal of the pilot case LCAs

The pilot case LCAs is intended for helping businesses and stakeholders to identify environmental hotspots of the solid biomass supply chain and the effects of their interventions in this chain.

The LCA shall supply consistent environmental impact results to support the sustainability assessment within SecureChain.

Thus the pilot case LCAs responds to the following question: What are the potential environmental implications for introducing a pilot case with one or more scenarios in the solid biomass supply chain for generating heat, electricity and cooling in comparison to a reference scenario based on current practice for generating heat, electricity and cooling.

The reason for publishing LCA results are to contribute to the development of the bioenergy sector in Europe by interventions from SMEs.

The intended audience of the report are businesses and stakeholders which use solid biomass sources in electricity, heating and cooling and LCA experts in the field of bioenergy.

The report is intended to be disclosed to public. Results are not intended to support comparative assertions.

Scope of the tool

The following sections describe the general scope of each LCA with regard to the specific research questions. This includes,

- the identification of specific product systems to be assessed
- the product function(s), functional unit and reference flows
- the system boundary
- allocation procedures

- cut-off criteria of the study.

The functional unit is the "quantified performance of a product system for use as a reference unit" (ISO 14044). It is defined for each pilot case LCA.

The process diagram gives a generic overview of life cycle stages included in the system boundaries. For each pilot case a process diagram is established.

Multi-output Allocation

Multi-output allocation generally follows the requirements of ISO 14044, section 4.3.4.2. As side flows are per definition co-products of multi-output processes allocation is required at processing stage. Economic allocation was chosen as the appropriate method.

End-of-Life Allocation

The modelling approach applied does not apply any allocation at end of life for e.g. bottom ash.

Selection of LCIA Methodology and Impact Categories

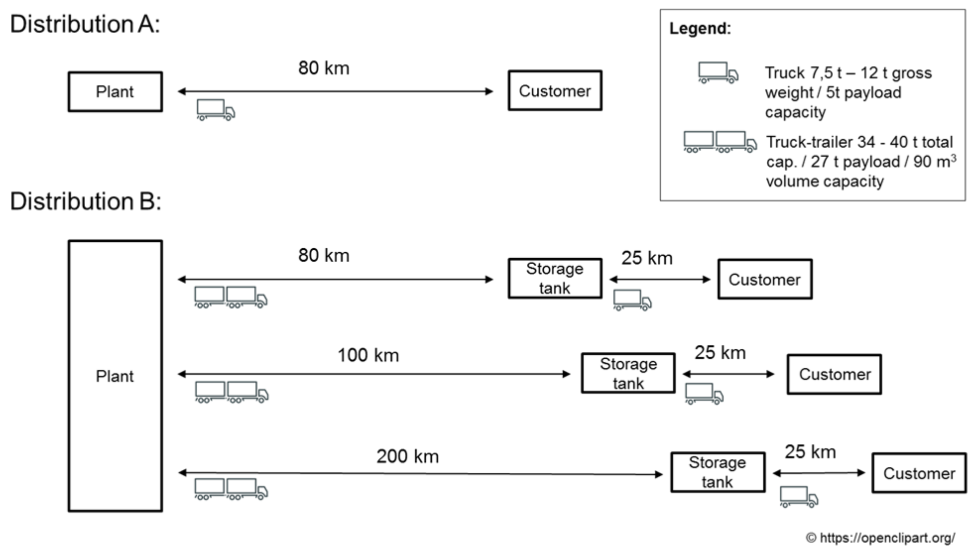
The LCA for the pilot cases follows an attributional approach. Consequential attempts are addressed in some pilot cases and only in a qualitative way.

Climate Change/Global warming potential is assessed as environmental impacts in most of the pilot cases. If other data than GHG emission data was available also other impact categories, such as Acidification potential is considered. The IPCC 2014 characterisation factors from the 5^{th} assessment report are applied. The IPCC characterisation factors are recommended by most carbon footprinting standards (ISO 14067, GHG Protocol, PAS 2050).

6.4.2 Model region Catalonia (ES)

ES.1	**Sala Forestal (Catalonia)**	**Geographical scope:** EU
Product system:	Different logistical concepts to transport wood chips to customers, Distribution system A compared to distribution system B	
Functional unit:	1 ton of transported wood chips	**Time relevance:** Not specified
Approach:	LCA limited to transport emissions	

Process diagram:



Only transport emissions are included. For the reference scenario (A) a truck with 7.5-12 t (Euro 4) is considered with a distance of 80 km. For scenario B a truck-trail 34-40 t (Euro 4) with the distances of 80, 100 and 200 km to storage tank stations and a truck 7.5-12t with 25 km radius to reach costumers is considered.

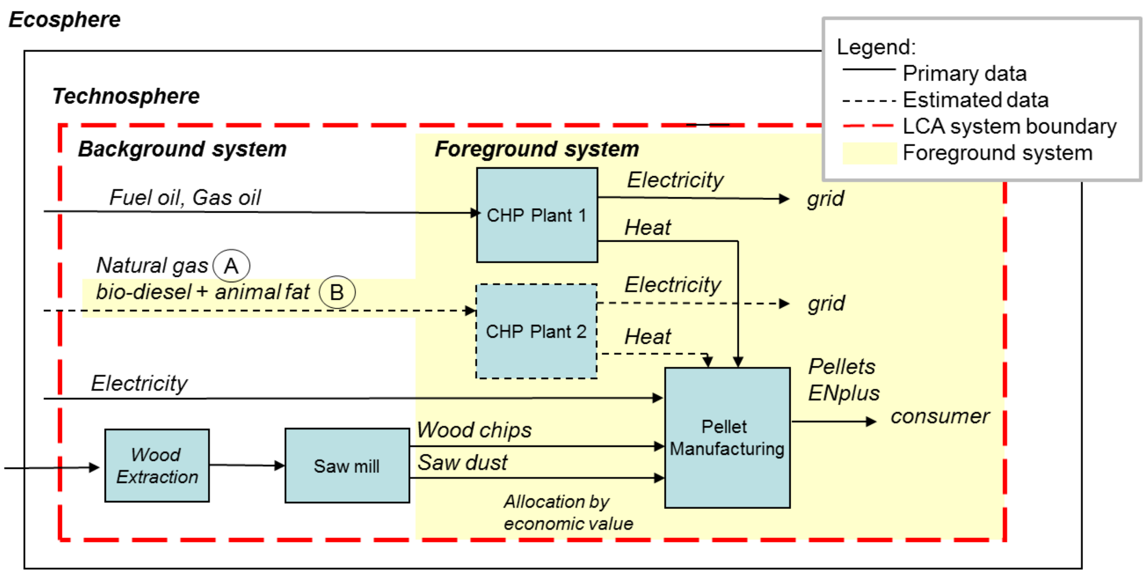
The infrastructure for road and transport vehicles as well as the storage tank is not considered. The company also stated that a transport company is contracted to arrange the long-distance transports. This means that the transport company is also only paid for full cargo rides. Empty rides, if any, are not charged and are therefore also not considered in the assessment. Empty rides are therefore only considered with small-distance transports and the own vehicle fleet.

Estimated transported quantity in A: 50,000 tons; transported quantity in B: 180,000 tons, Estimated additional biomass mobilised: 130,000 tons

LCA Results:	Scenario A: 20 kg CO_2-eq./t transported wood chips Scenario B: 12 kg CO_2-eq./t transported wood chips GHG reduction A to B: 40%	**GHG savings** (wood chip chain vs. fossil chain): 93%

ES.3	**Novalia Sinergie**	**Geographical scope:** Catalonia
Product system:	Enlargement of pellet manufacturing plant and providing additional process heat from CHP plant 1 fuelled with fuel oil and gas oil (status quo), from CHP plant 2 fuelled with natural gas (A), or with waste (e.g. animal fat) (B)	
Functional unit:	1 ton of EN plus certified pellets	**Time relevance:** Not specified
Approach:	Attributional LCA (Software: GaBi 6.0)	

Process diagram:



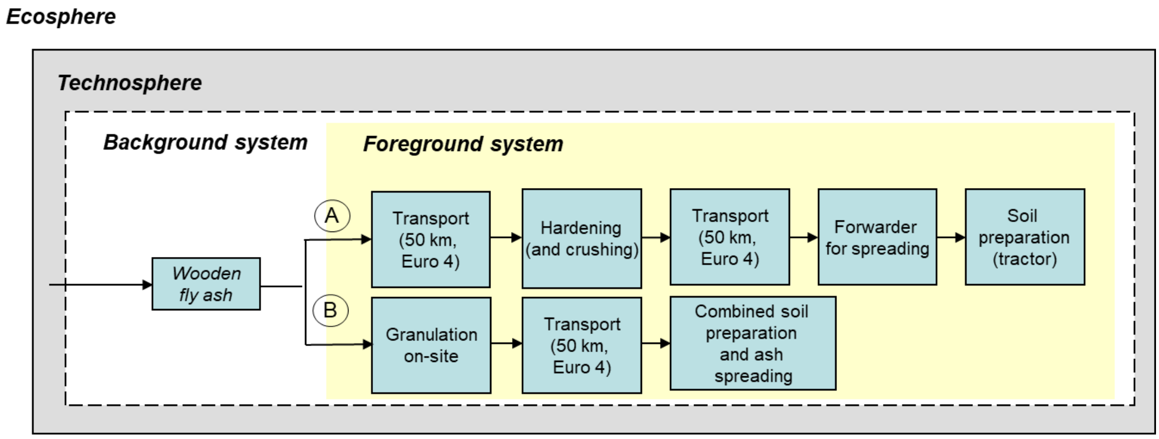
Description:

The Novalia Sinergie pilot project consists of a pellet manufacturing plant, which aims to enlarge production to 60,000 tons per year. Sawdust and wood chips (economic allocation by price), both 100% from pinewood from nearby sawmills, are used as raw material for the pellets, which are EN plus certified. Electricity for the production process is coming from the national grid. Heat is derived from CHP plant owned by the company, which runs on fuel oil and gas oil. The long-term goal of the company is to produce heat from a second CHP plant fuelled by bio-diesel, animal fat and natural gas.

LCA Results:	GHG emissions 946 to 1048 kg CO_2-eq. per ton of produced pellets (depending on price scenarios) (56-62 kg CO_2 eq./MJ)	**GHG savings** (status quo

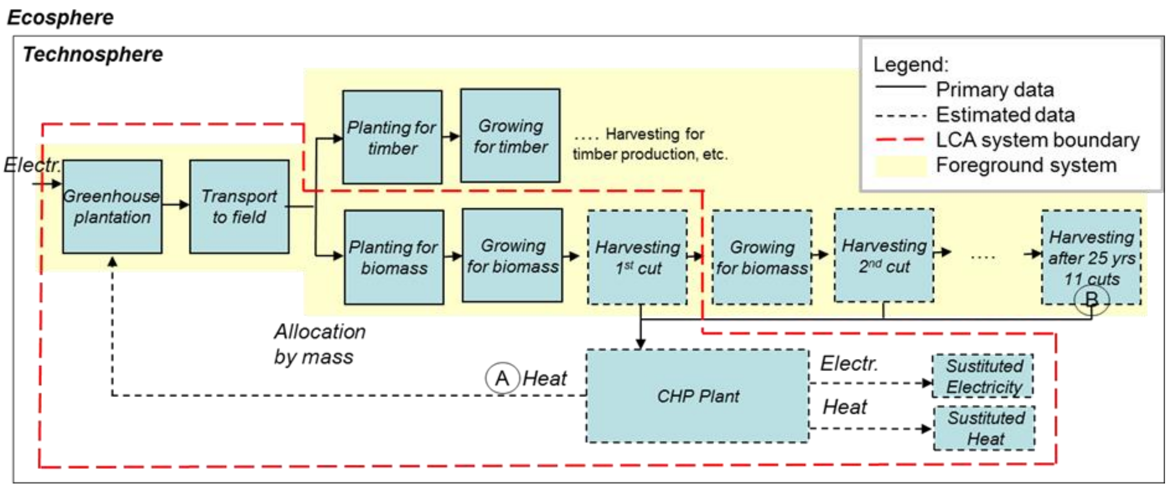
	80 to 89 % of the GHG emissions derive from the heat produced in CHP Scen A: If heat is provided with natural gas, then GHG emissions result in 752 to 853 kg CO_2-eq. (44-50 kg CO_2 eq./MJ) Scen B: If heat is allocated as "waste heat" or provided from waste, then GHG emissions result only in 104 to 205 kg CO_2-eq. (6-12 kg CO_2 eq./MJ) Status quo to Scen A: 23% GHG could be saved.	vs. fossil chain): 22% (Scen B vs. fossil chain): 73%

6.4.3 Model region Småland (SE)

<table>
<tr><td><u>SE.1</u></td><td>Skogsbränsle Småland AB</td><td rowspan="2">Geographical scope:
Sweden, Finland</td></tr>
<tr><td>Product system:</td><td>Loose ash spreading (A) in comparison to pelleting of wood ash and spreading to forest (B)</td></tr>
<tr><td>Functional unit:</td><td>1 ton of ash spreaded in the forest</td><td rowspan="2">Time relevance:
Not specified</td></tr>
<tr><td>Approach:</td><td>Attributional LCA (Software: GaBi 6.0)</td></tr>
<tr><td colspan="3">Process diagram:

</td></tr>
<tr><td colspan="3">Description:
Currently the ashes are returned in loose form to the forest. This action does not appeal to everyone, because the forest looks dirty for several years after the ash spreading. If the technology of ash pelletisation can be adopted and the ash can be spread on the felling area, it would be most certainly possible to attract a large number of forest owners.
Today exists a prototype plant in Finland for pelleting of ash. The project explores the possibility to acquire a similar facility to be installed at one of the local biomass collection sites, and also develop a forwarder or tractor-mounted spreaders of ash pellets. The spreading equipment will be attached to the existing equipment of soil preparation.</td></tr>
<tr><td>LCA Results:</td><td>GHG emissions in A: 54.7 CO_2-eq./ton spreaded ash
GHG emissions in B: 43.5 kg CO_2.eq./ ton spreaded ash
A to B: 20% GHG could be saved.</td><td>No comparison with fossil chain.</td></tr>
</table>

SE.2 + SE.3	Värnamo Energi / Lessebo Fjärrvärme	**Geographical scope:** Sweden
Product system:	A comparison of pellet (A) and wood chip fired boilers (B) to substitute oil fired boilers.	
Functional unit:	1 MJ of thermal energy produced	**Time relevance:** Not specified
Approach:	Average GHG emission of existing LCA studies	
Process diagram:		
Description: The following study is based on a literature research. The focus is primarily on Swedish case studies or - if not otherwise available - comparable reports from Scandinavia or Central Europe because of the fact that forestry practices and the state of the technology of district heating systems can vary widely between countries and thus would distort the results. The current and planned boiler capacities to replace with wood or pellet fuelled boilers sums up to 63.72 TJ. The extraction of raw materials is limited to Swedish region (no imports considered).		
LCA Results:	LCA results of **oil-fired boilers** range from 81 to 103 g CO2 eq./MJ (Sikkema et al., 2010; Petersen, 2006; Uppenberg et al., 2001; Jungmeier et al., 2003; Mahalle, 2000) with the median value of 92 g CO2 eq./MJ. The fossil fuel comparator for heat of the European Commission (2010b) is 81 g CO2 eq./MJ. LCA results of **pellet** production and combustion (A) in literature (Sikkema et al., 2010; Hagberg et al., 2009; Hansson et al., 2015) range from 2.99 to 5.06 CO2 eq./MJ with a median value of 3.35 g CO_2 eq./MJ. Other studies from Austria and Norway exhibit slightly higher but still similar results (4.60; 5.80; 6.42 g CO_2eq / MJ) (Jungmeier et al., 2003; Petersen Raymer, 2006; Sjølie and Solberg, 2011). Also the default values for pellets of Giuntoli et al. (2015) are higher. LCA results of **wood chip** production and combustion (A) in literature (Lindholm et al.,2010; Mälkki and Virtanen, 2003; de la Fuente et al., 2016) range from 2.81 to 4.26 CO2 eq./MJ with a median value of 3.25 g CO2 eq./MJ.	GHG saving In both cases 96%

6.4.4 Model region Western Macedonia (EL)

<table>
<tr><td><u>EL.1</u></td><td>AZ Bioenergia</td><td rowspan="2">Geographical scope:
Western Macedonia</td></tr>
<tr><td>Product system:</td><td>Biomass production with short rotation coppices (Paulownia tree) (1st cut) and CHP (A); Biomass production with short rotation coppices (entire tree life) and CHP (B)</td></tr>
<tr><td>Functional unit:</td><td>1 MJ of thermal energy produced out of combustion of paulownia after its 1st cut (A) and of paulownia grown for 25 years (11 cuts) (B)</td><td rowspan="2">Time relevance:
Not specified</td></tr>
<tr><td>Approach:</td><td>Attributional LCA</td></tr>
<tr><td colspan="3">Process diagram:
</td></tr>
<tr><td colspan="3">Description:
As paulownia trees were not harvested in time before conducting the LCA, the biomass yield had to be estimated. Data of Durán Zuazo et al. (2013) show a high range of biomass yield from 1.7 t to 14 t per ha d.m. Therefore, it was decided to use a minimum and a maximum scenario for the biomass yield. In case of AZ Bioenergia, where the plant density (stands per ha) is higher, it results to a biomass yield of 2.5 to 20.9 t per ha (medium scenario with the yield of 11.7 tons per ha d.m. was further used). The mean value of lower heating value (LHV) of paulownia clones in Andalucia was taken for calculating the energy output. It was assumed that in total 10.6 tons of biomass can be produced which results in approx. 86 GJ.</td></tr>
<tr><td>LCA Results:</td><td>GHG emissions (minimum yield): 0.23 kg CO_2-eq. per MJ_{th}
GHG emissions (medium yield): 0.13 kg CO_2-eq. per MJ_{th}
GHG emissions (maximum yield): 0.03 kg CO_2-eq. per MJ_{th}</td><td>GHG savings
(paulownia med. Yield vs. fossil chain):
30%</td></tr>
</table>

	(in comparison: SRC from Eucalyptus has GHG default of 0.026 kg CO_2eq./MJ) Fossil fuel comparator: 0.012 kg CO_2e	(paulownia max. yield vs. fossil chain): 82%

EL.2	Alfa Wood – Pindos SA	**Geographical scope:** Wester Macedonia
Product system:	Increase of bark use in the boiler for heat supply for medium density fibre boards (MDF) production line; Share wood chips and bark for the boiler: 80:20 (status quo), 90:10 (A), 100:0 (B); 0:100 (C)	
Functional unit:	1 MJ of thermal energy	**Time relevance:** Not specified
Approach:	Attributional LCA	

Process diagram:

Relation (Bark:Wood chips)	Status quo (80:20)	Scenario A (90:10)	Scenario B (100:0)	Scenario C (0:100)
Bark	9,000,000.00	10,240,491.68	11,509,609.44	-
wood chips	2,250,000.00	1,137,832.41	-	10,318,984.62
Total input	11,250,000.00	11,378,324.09	11,509,609.44	10,318,984.62

To calculate the energy output, the lower heating value (LHV) as received by the company was considered for bark and wood chips. It was analysed by CERTH/CPERI. Bark has a LHV as received with 2331.04 cal/gr and wood chips a LHV as received with 1881.5 cal/gr. For the yearly use of 9,000 tons of bark and 2,250 tons of chips this is in total 29,322.12 MWh used to feed the boiler. The boiler efficiency is according to the company 95% this corresponds to 27,856.01 MWh which is used in the MDF production line and for heating the offices.

Besides the calculation of the energy output the emissions to air were converted to absolute mass values. The moisture content in the flue gas ranges from 10 to 50%. It strongly influences the amount of CO and NO_X in the flue gas. Therefore, it is necessary to show results for several scenarios. For the status quo the average value of 30% moisture content is used. The influence of minimum (10%) and maximum (50%) moisture content on overall results will be assessed.

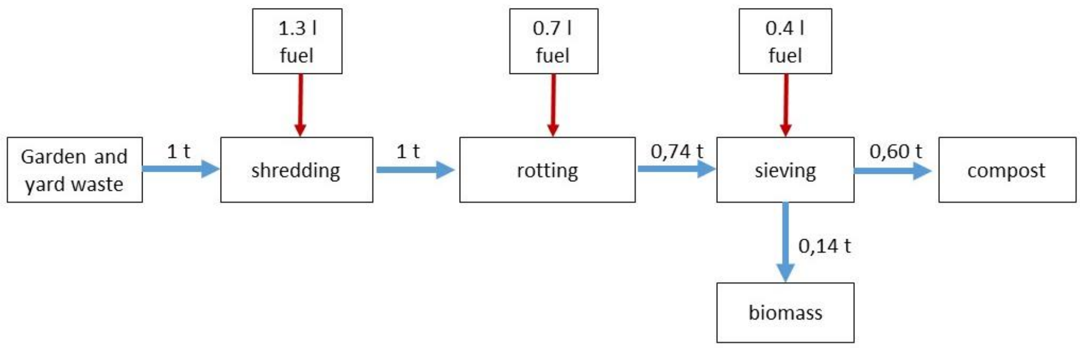
LCA Results:	Status quo: 10.06 g CO_2e/MJ Scen A (90:10): 8.47 g CO_2e/MJ Scen B (100:0): 6.84 g CO_2e/MJ Scen C (1:100): 21.61 g CO_2e/MJ Reference Scenario (heavy fuel oil): 83.97 g CO_2e/MJ	**GHG savings** (Scen A vs. fossil chain): 90%

6.4.5 Model region North Rhine-Westphalia (DE)

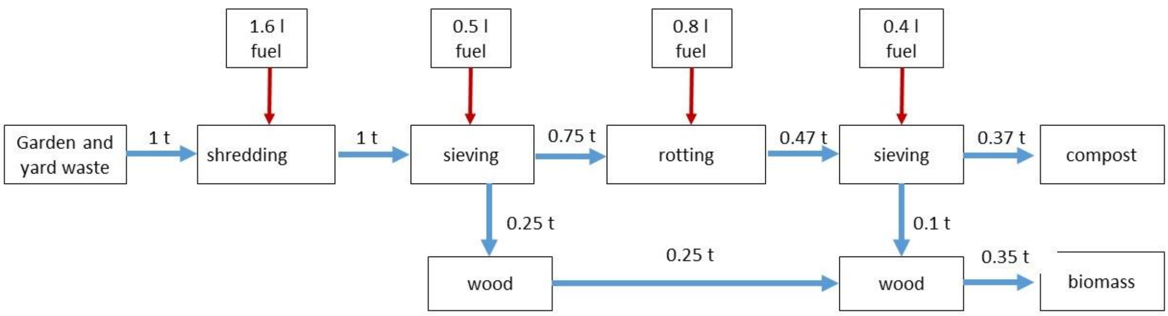
DE.3	AVEA	**Geographical scope:** North Rhine-Westphalia
Product system:	Comparison between the existing composting procedure (A) and the optimised biowaste sorting to separate biomass (B)	
Functional unit:	1 tonne of garden and yard waste	**Time relevance:** Not specified
Approach:	Attributional LCA	

Process diagram:

Scen A (Status quo):



Scen B (pilot):



Data on used machinery and equipment as well as transport distances were provided by case study partner from AVEA. Emissions mainly occur from fuel use and the rotting process. Data inventories derive from Ecoinvent III as well as GaBi professional series ((Frischknecht and Jungbluth, 2007). Rotting data are based on own investigations and an extensive literature research, the input composition of garden and yard waste as input was defined following Boldrin et al. (2011), Hanc et al. (2011), Andersen et al. (2011), Knappe et al. (2012), Ortner et al. (2013), Vogt et al. (2002), Edelmann und Schleiss (2001) as well as Amlinger et al. (2005).

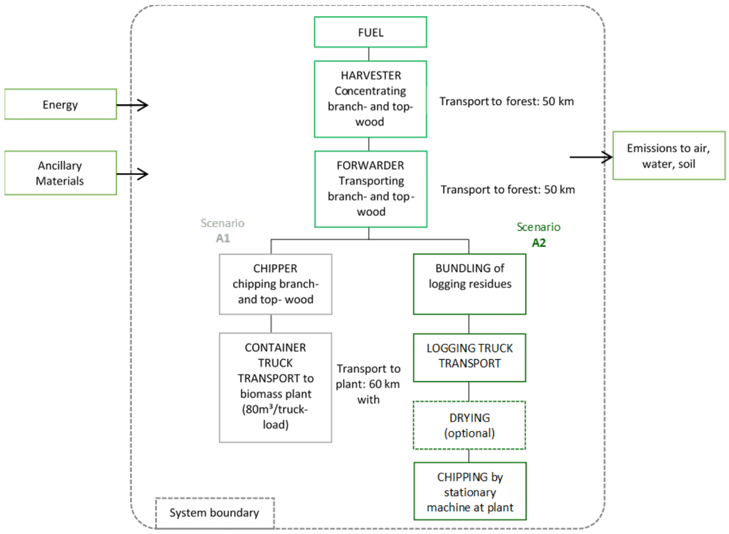
For the used fuel the German Diesel mix was used in both scenarios.		
LCA Results:	GHG emissions Scen A: 77.05 kg CO_2-eq/t garden and yard waste (only shredding and sieving: 1.00 kg CO2-eq./t)* Reference System Scen A: 131 kg (only shredding and sieving: 7.33 kg CO2-eq./t)* GHG emissions Scen B: 70.24 kg CO_2-eq/t garden and yard waste Reference System Scen B: 328 kg Through the optimised process the direct emissions can be reduced about 11 %. Another 57 % of GHG emissions can be saved from using biomass instead of fossil fuel for district heating. *For the comparison with the fossil reference system to generate the GHG indicator, emissions from rotting process and compost utilization cannot be considered as it is wood waste (so any up-stream burden are not accounted).	**GHG savings**: (biomass from green waste vs. fossil chain) 100%

6.4.6 Model region Gelderland & Overijssel (NL)

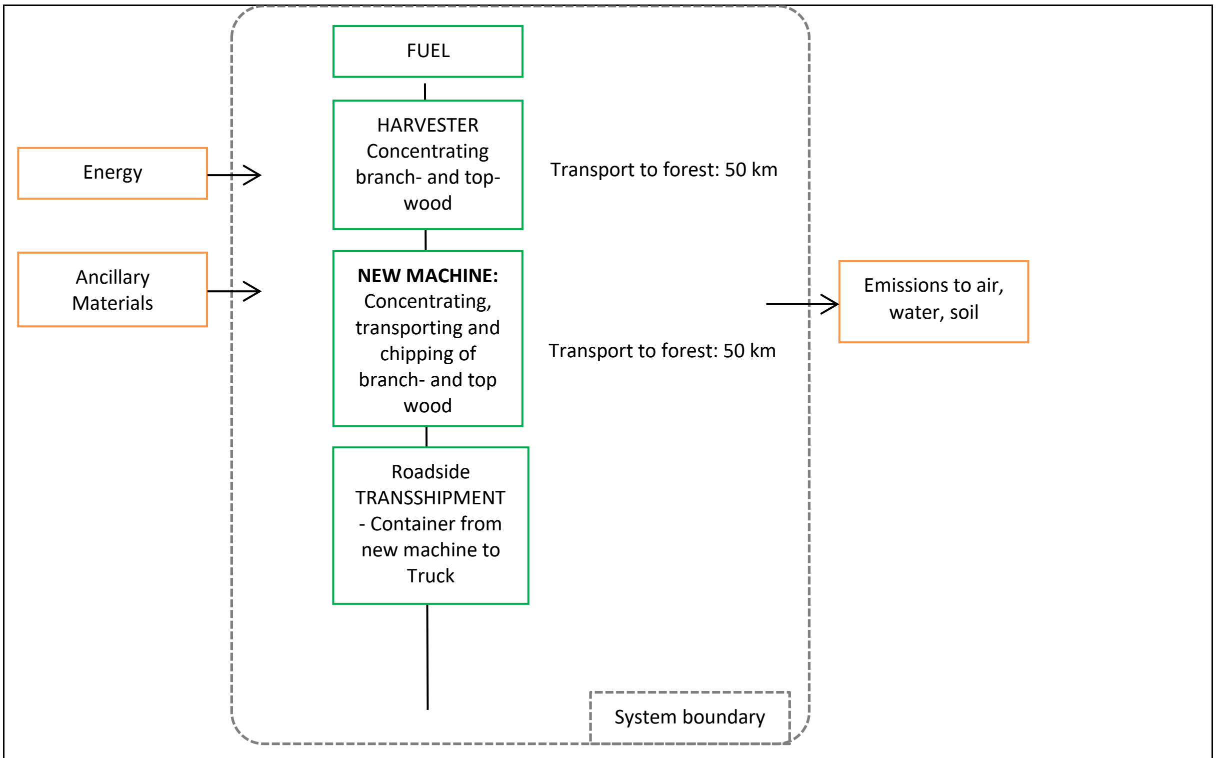
NL.2	Hissink & Zonen	**Geographical scope:** Gelderland & Overijssel (NL)
Product system:	Comparison of the current situation of a forwarder for collection and a chipper for comminution of branch and top wood (A) and a new machine combining the collection, chipping and transportation in one stage (B)	
Functional unit:	1 tonne d.m. of chipped wood	**Time relevance:** Not specified
Approach:	Attributional LCA	

Process diagram:

Status quo (A):



Pilot (B):



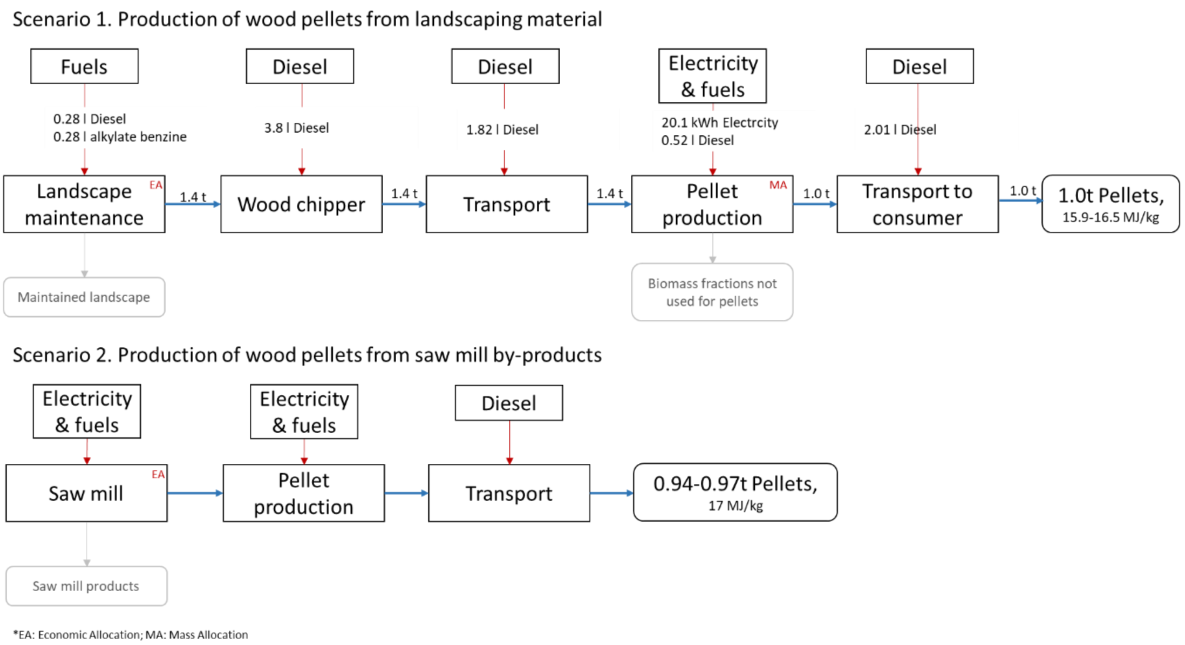
The study is based on personal information from the company Hissink & Zonen but also on LCA literature to generate GHG factors of forwarding and chipping (Manzone, 2015; Kärhä and Variamäki 2006; (de la Fuente et al., 2017; Lindholm et al., 2010). Transport distances and diesel consumption are estimated, as these data are difficult to calculate. It has been tried to focus on primarily Dutch literature, more precisely case studies, or - if not otherwise available - comparable reports from other European countries with similar forest management practices. Fundamental information of the Dutch forestry situation rest upon a study called “The harvest of logging residues on the Dutch forests and landscape” by the forestry institute *Probos*, located in Wageningen (Kuiper, 2006).

Emissions of the machine transport to the forest and truck transport of wood chips from roadside to the biomass energy plant are included.

LCA Results:	GHG emissions A1: 41 – 53 kg CO_2-eq./t d.m. wood chips GHG emissions A2: 50 – 58 kg CO_2-eq./ t d.m. wood chips GHG emissions B: 29 kg CO_2-eq./ t d.m. wood chips The LCA shows GHG savings of 18-25 kg CO_2eq Mg DM^{-1} of the new machine in comparison to the current situation (scenario A,B) of harvesting and chipping of branch and top wood. Savings A to B: 18-25 kg CO_2eq Mg DM^{-1}	No comparison with fossil chain.

NL.3	**Bruins & Kwast**	**Geographical scope:** NL
Product system:	Production of wood pellets from landscaping materials also called ‘Streekpellets’.	
Functional unit:	**Scenario 1:** 1 t of ‘Streekpellets’ at consumer with an energy content of 15.9-16.5 MJ/kg (LHV). **Scenario 2:** Pellets from saw dust, as they have a higher energy content of 17 MJ/kg (LHV) only 0.94-0.97 t are required to provide the same amount of energy as 1 t of Streekpellets.	**Time relevance:** 2018
Approach:	Cradle to gate (incl. transport to consumer). **Scenario 1:** Pellets are produced from landscaping material. Allocation is required at process ‘harvest of biomass’, this is based on costs covered by biomass vs costs covered by maintenance. Mass allocation is applied at pellet production, during the sizing of wood 85% are used for pellets while 15% are used for other purposes. **Scenario 2:** Pellets are produced in Germany from saw mill by-products. Allocation at sawmill is based on economic value of saw mill products. Pellets are transported to the consumer in the Netherlands.	

Process diagram:



<table>
<tr><td colspan="3">Scenario 1: Production of wood pellets from landscaping material (Streekpellets):

Biomass is harvested from landscape elements such as hedges, single-line tree stands, small forests as well as parks and avenues. Biomass is harvested with cranes and motor saws and chipped. The woodchips are transported to the pellet production site where they are pre-treated, sized, dried and pelletised. Wood chips produced on site are used as a fuel for the drying process. The finished product is sold in bulk of 2-15 tonnes to customers within a radius of 50 km.

Scenario 2: Production of wood pellets from saw mill by-products

To be able to compare Streekpellets with the most commonly used pellets in NL, scenario 2 was defined. Most pellets consumed in NL are produced from saw mill by-products and are imported from Germany. The thinkstep LCA dataset ‘EU-28 Wood Pellets’ is representative for this technology and is used to approximate emissions associated with the production. Also transport of 700km to the consumer in NL is assumed and included for scenario 2.</td></tr>
<tr><td>LCA Results:</td><td>Scenario 1:

GWP for 1 t of pellets, equal to 15.9-16.5 GJ/t (LHV): 60 kg CO_2e. Most are associated to electricity required for the pelletising process (56%) and the chipping of the landscape material (19%). Harvest is associated with 4%, transport of woodchips to the pelletising plant with 9%, sizing and drying with 2%, transport to the consumer with 10%.

Scenario 2:

15.9-16.5 GJ of saw mill residue pellets (0.94-0.97 t): 115-119 kg CO_2e (62% pellet production, saw milling and silviculture; 38% transport)

Production and supply of 1 t of Streekpellets is in the assessed scenarios associated with lower emissions (-55-59 kg CO_2e) than pellets from saw mill residues sourced from Germany.</td><td>GWP savings:

(pellets vs. fossil chain):

94%</td></tr>
</table>

Citation, Acknowledgement and Disclaimer

Scherhaufer S., Obersteiner G., Gollnow S., Mayrhofer J., Pagels M., Kies U. 2018. Sustainability implementation and certification of solid bioenergy pathways – Case studies of the EU H2020 project SecureChain. WP4 Final report D4.3. SecureChain, Horizon 2020 project no. 646457, University of Natural Resources and Life Sciences, Institute of Waste Management (BOKU-ABF) and DINCERTCO. Vienna, Berlin. www.securechain.eu

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