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DETERMINATION OF THE ENVIRONMENTAL IMPACT OF A NEW BIOMASS LOGISTICS CHAIN

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ABSTRACT

Agricultural residues (prunings) coming from permanent plantations and orchards constitute a significant and largely unused potential for renewable energy. The EuroPruning project, respecting the impact on the environment, aims to turn prunings into a valuable fuel source by developing solutions for their harvesting, transportation and storage that will create growth in the European biofuels market. To determine the environmental consequences of the Pruning-to-Energy (PtE) logistics chain, a Life Cycle Assessment study will be conducted. In this study the PtE scenarios will be compared to three current practices: open field burning, mulching and use for domestic heating. In the paper an outline of the assessment methodology and consequent challenges are provided.

Introduction

There is a wide variety of different kinds of biomass that could potentially be used for the production of renewable energy. Agricultural residues (prunings) coming from permanent plantations and orchards constitute a significant and largely unused potential for renewable energy. The EuroPruning project aims to turn prunings into a valuable fuel source by developing solutions for their harvesting, transportation and storage that will create growth in the European biofuels market. At three demonstration sites the developed solution will be tested and demonstrated. The sites cover plantations of apples and cherries in Germany, peaches, almonds and olives in Spain and grapes in France. Whether or not a given biomass flow is suitable for energy production does not only depend on the technological possibilities and the potential economic feasibility of the conversion process, but as well of the whole of the impacts on the environment and society. To determine the environmental consequences of the Pruning-to-Energy (PtE) logistics chain, a Life Cycle Assessment study will be conducted. In this study the PtE scenarios will be compared to three current practices: (open field burning, mulching and use for domestic heating). In this article an outline of the assessment methodology and consequent challenges are provided.

Sustainability assessment

The European Union considered Sustainable Development as a vital objective for European policies, incorporating it in the Amsterdam treaty of 1997. Sustainable Development consists of three pillars: Economic Prosperity (i), Environmental Protection (ii) and Social Equity and Cohesion (iii). Within the EuroPruning project the three pillars of sustainability are considered in a Life Cycle Thinking approach to enable a founded choice for a sustainable utilisation scenario for orchard prunings. In this paper the initial approach for the assessment of the environmental impacts by application of a Life Cycle Assessment (LCA) is presented.

Environmental assessment: LCA according to the ISO Norm

According to the ISO 14040:2006 Norm LCA is defined as "the compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle." (ISO 2006a)

The technique examines every stage of a product life cycle, from raw materials extraction, through manufacture, distribution, use, possible re-use/recycling and final disposal. The phases of LCA, according to ISO 14040:2006 are presented in Figure 1.

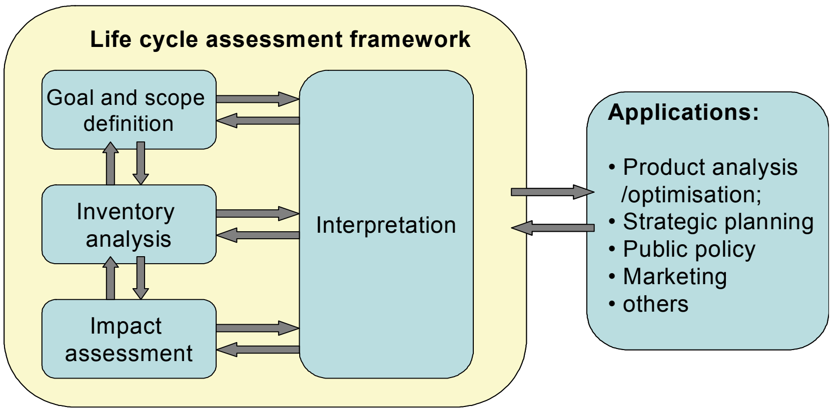

Figure 1. Phases of LCA, according to ISO 14040:2006 (adapted from ISO 2006a)

Goal and scope definition

A goal and scope definition is the phase in which the initial choices, that will determine the working plan of the entire LCA, are made. The goal of the study is formulated in terms of the exact question, target audience and intended application. The scope of the study is defined in terms of temporal, geographical and technological coverage, and the level of sophistication of the study in relation to its goal (Guinée et al., 2002).

Life Cycle Inventory

Within the phase of inventory analysis for each "life stage": (i) the inputs (in terms of raw materials and energy) and (ii) outputs (in terms of emissions to air, water and solid waste) are calculated. The results of the inventory are aggregated over the entire life cycle.

Allocation of flows and releases

In many systems, including pruning to energy (PtE) not only one product of service is generated. For example PtE's main function is produce electricity/heat, however at the same time a co-production of wastes and gas-exhaust may take place (generation of ash, NO_x, CO_2 or SO_2 from combustion processes). Thus the material and energy flows as well as associated environmental releases should be allocated to the different products according to clearly stated procedures (ISO 14044:2006). The ISO norm prescribes that the allocation should be wherever possible avoided by dividing the unit processes to be allocated into two or more sub processes and collecting the input and output data related to these sub processes as well as by expanding the product system to include the additional functions related to the co-products.

Life Cycle Impact Assessment and Results Interpretation

Life cycle impact assessment (LCIA) is the phase in which the inventory analysis output is further processed and interpreted in terms of environmental impacts and social preferences. LCIA requires the comparative evaluation and aggregation of various emissions, resources and other disturbances such as land use and noise. An aggregation of these "stressors" inevitably contains apples-and-oranges comparisons (Hertwich and Hammitt, 2001). Figure 2 summarises the overall framework of LCIA. It shows the relation between life cycle inventory results, impact categories, category indicators and category end point(s). The impact category Acidification is used to illustrate this concept.

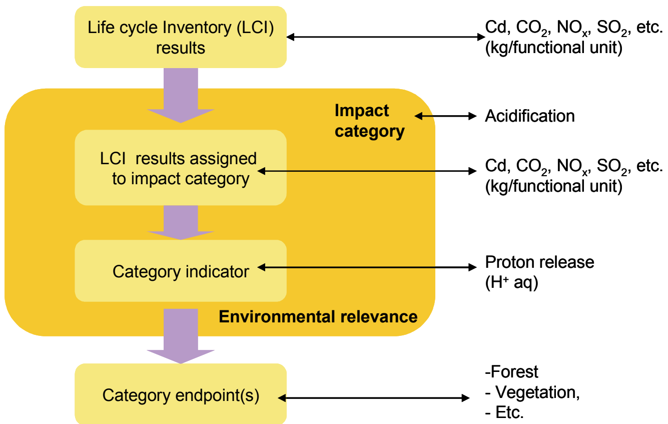

Figure 2. The conceptual framework for defining category indicators (adapted from ISO 2006b)

ISO 14044:2006 defines also the term “environmental mechanism”, which is “a system of physical, chemical and biological processes for a given impact category, linking the LCI results to category indicators and to category endpoints” (ISO 2006b).

Endpoints, according to ISO, there are physical elements in the environmental mechanism of an impact category of direct concern to society. Udo de Haes and Lindeijer (2002) define Areas of Protection as classes of endpoints. The midpoints are all elements in an environmental mechanism of an impact category between interventions and endpoints. Four areas of protection (valuable in themselves or to humans) were identified according to JRC (2011): human health, man-made environment, natural environment and natural resources.

The difficulty of an LCIA lies in the fact that stressors (such as emitted substances) cause unequal effects to different people and ecosystems according to different mechanisms of action and different times. Even if the mechanisms of action are the same as for the greenhouse gases their dynamic behaviour and therefore time horizon differs (Hertwich and Hammitt 2001). The determination of the comparative significance of one environmental impact relative to another is hence not primarily question of measurement, it is one of judgement.

LCA approach and methodology for EuroPruning and accompanying dilemmas

Goal

The goal of the study is, according to the Description of Work (DOW) of the EuroPruning project: “to assess the environmental impacts potentially derived from the utilization of agricultural wood pruning biomass as energy feedstock.”

Scope: cradle-to-gate or cradle-to-grave?

Within the DOW it is specified, that the environmental assessment will concentrate on the value chain until the distribution to the final user (will not incorporate the assessment of all the impacts related to the final use of the fuel). This seems to be a valid specification for the economic assessment, where the price that is paid for the final solid fuel produced replaces all the economic impacts of the various options of energy production later on in the value chain. Specific costs of investment and operation of installations ‘after the gate’ are not relevant for the comparison of various options of the utilisation of agricultural wood pruning biomass. For the social assessment a limitation to the logistic chain up unto the energy production facility gate is valid as well. The direct social impacts of the various options of what to do with the generated prunings are relevant, whereas the social impacts of energy production is out of the scope of the EuroPruning project.

However, as for the environmental assessment, the picture is more complex. The sole reason for thinking about the energetic use of agricultural prunings is the potential substitution of conventional energy. Therefore, this environmental gain of substituting currently produced energy should also be reflected within the environmental assessment. There is not such a thing as market price in environmental terms. For the environmental assessment therefore a standard, generally applied energy transformation process will be considered. This approach is followed as well in similar, more limited studies (Boschiero et al., 2013;

Picchi et al., 2013). In the first place the scope of the LCA will be the comparison of current practices of agricultural prunings use with the improved logistics chain for energy purposes that will be developed within the EuroPruning project. For this purpose, as explained above, the incorporation of the energy transformation process is unavoidable. However, it is likely, that prunings as a fuel will be compared to other biomass fuels, such as forest residues or biofuels from energy plantations. In that case a comparison of the production and logistic chain of the biomass fuels up unto the gate of the energy transformation process could be considered, thus excluding the impacts during the combustion (or gasification, pyrolysis etc.) process.

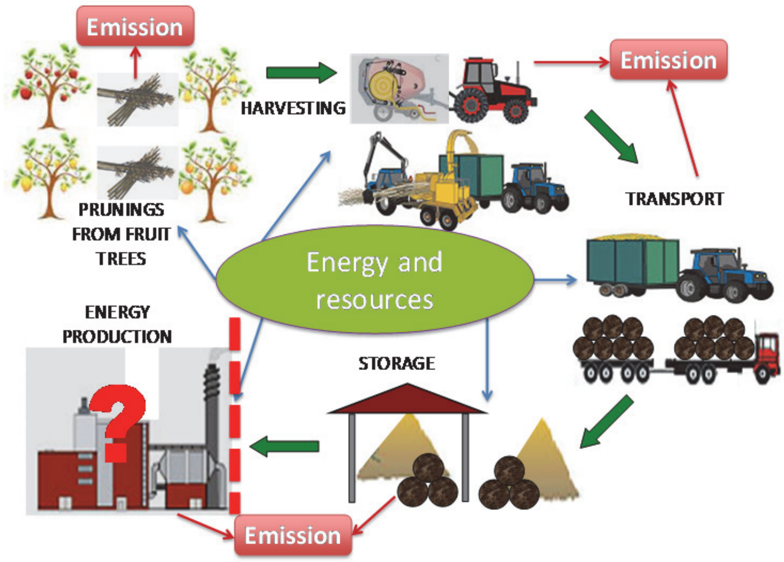

Figure 3. The life cycle scope within the EuroPruning project (Dyjakon et al., 2014)

All scenarios to be compared have then the same environmental gain: energy production, thus substituting conventional energy sources. A study comparing various sources of solid biofuels could end at the delivery of a certain amount of contained energy to the gate of the final user.

Scope: Europe wide?

Within the EuroPruning project a number of project deliverables will clearly lead to results reflecting the European Union as a whole. Detailed estimates for prunings generation in the entire Union will be provided. However, as the project intention is to developed a new logistic chain for pruning biomass, data deriving from field studies will only reflect the specific cases studies (e.g. soil GHG emissions from mulching test in German apple orchards). To overcome this discrepancy, in a first approach detailed LCA investigations based on the project demonstration sites will be undertaken as a kind of indicator studies.

The demonstration sites cover plantations of apples and cherries in Germany, peaches, almonds and olives in Spain and grapes in France. Based on these Europe wide estimated and conclusions will be drawn.

Inventory analysis

In the inventory analysis for all life cycle stages the resource consumption and emissions will be determined and consequently aggregated (see Figure 3). For the following stages data stemming from the project case studies will be used:

– effects of mulching. Both greenhouse gas emissions, the introduction of organic carbon and nutrients to the soil as well as the leaching thereof will be considered.
– prunings harvesting. The construction and use of the developed harvesting machinery will be considered.
– storage. During the storage the pruning material will be subject to various decomposition processes. The effects thereof will be determined during field trials.
– biomass composition. The composition and other parameters of both fresh (before mulching) and stored (before energetic use) pruning biomass will be determined. The heavy metal content however, will be taken from literature sources, as a thorough analysis cannot be afforded from the project budget.

Interviews amongst farmers and farmer unions about the growing and pruning of permanent crops will provide additional information for the LCA modeling. The remaining necessary data will be taken from standard processes contained in the applied LCA software as well as from literature sources.

Impact assessment methodology

The Life Cycle Impact Assessment (LCIA) methodology to be applied within the EuroPruning project will be a mid-term assessment due to the reasons described above. The JRC recommends a number of methods in its Handbook (JRC 2011). Within the EuroPruning project the methods CML2002 and IMPACT2002+ will be compared, after which one will be chosen for the entire environmental assessment (Guinée et al., 2002; Jolliet et al., 2003).

Interpretation: crediting

When comparing various systems in an LCA, some of them may have by-products or services as an output that others lack. The additional function related to the by-products can be accounted for as credits in form of negative energy and material flows equivalent to the quantities of replaced primary products are assigned to respective processes. The production of those products is accounted for as a positive effect, the called “credit”. Alternatively, a ‘basket of services’ can be created, in which all by-products are contained. Every scenario that does not provide with the by-product or service within the scenario itself, needs to account for the environmental burdens of the supplementary production of the by-product externally (outside the actual scenario). In Figure 4 the basket of services for the considered scenarios in the EuroPruning project is shown.

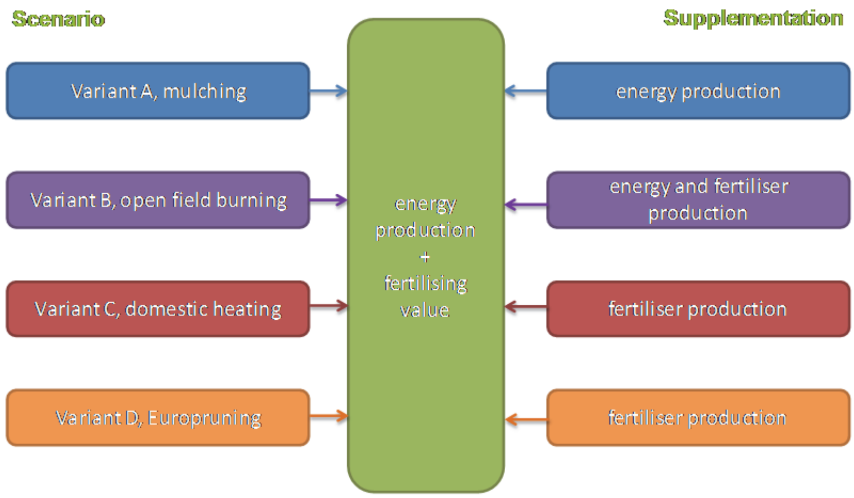

Figure 4. Basket of services for the EuroPruning project scenarios

The scenario of using agricultural woody prunings for energy purposes (variant D in Figure 4) produces energy, but lack the fertilising value of the prunings (which are not applied to the soil). Therefore additionally to the other environmental impacts, the burdens of the production of an amount of fertilisers equal to the value in the mulching scenario are to be added to the EuroPruning scenario.

Interpretation: soil depletion

Currently, LCIA methodologies consider the introduction of biomass matter into soil as a positive effect in terms of carbon sequestration and nutrient enrichment. However, taking away prunings for energy purposes could imply a further soil depletion, especially when the soil is sandy or poor in organic matter. Current LCIA methods do not consider the risk of soil fertility depletion (Cherubini et al., 2009; Milá et al., 2007; Boschiero et al., 2013), as this effect depends on the actual state of the soil. In general, LCA refers only to potential impacts, not considering the actual state of the environment. Within the EuroPruning project, a handbook for farmers that produce prunings will be published. In this handbook amongst other things, the danger of soil depletion will be considered, likely leading to guidance to remain the prunings on the fields in case of soils poor in organic carbon.

Interpretation: waste or product

Farmers grow permanent crops to produce fruits, olives, grapes etc. The pruning biomass is generated as waste, which is consequently mulched or burned. In current practice, pruning residues do not have a market value yet, their disposal rather poses costs to the farmers. This implies, that all environmental impacts related to the growth of the trees should be solely allocated to the agricultural products and not to the pruning residues. When comparing alternative uses of the pruning residues, the environmental burden of the tree growing could be neglected anyway, as it is identical for all scenarios. However, when comparing prunings as a fuel to other fuels, the pre-chain is relevant. At the moment the Pruning-to-Energy alternative becomes economically interesting for the farmers, pruning residues will have a positive value. The latter would imply, that part of the burden for the growing of the permanent crops should be allocated to the prunings residues. For the Euro-Pruning project this implies, that at first the fruit growing impacts can be neglected, but in later stages of the project may become relevant.

Conclusions

Within the EuroPruning project Life Cycle Assessment will be applied to determine the environmental impacts potentially derived from the utilisation of agricultural wood pruning biomass as energy feedstock. For this purpose data from literature, LCA software processes and from the planned field studies within the project will be used. The latter will comply: harvesting, storage, pruning composition and mulching. The LCA study will initially encompass the entire 'cradle-to-grave' of agricultural pruning residues, including a standardised energy production module. Part of the impact related to the growing of the fruits will be allocated to the produced prunings. Four scenarios will be compared: three current practices (open field burning, mulching and use for domestic heating) with the Pruning-to-Energy scenario. Energy produced or fertilising value achieved by soil application will be accounted for as environmental gains. The CML2002 or IMPACT 2002+ impact assessment method will be applied to determine the impacts of the use of prunings for energy purposes in three indicator studies: apples and cherries in Germany, peaches, almonds and olives in Spain and grapes in France.

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References

Boschiero, M.; Neri, P.; Zerbe, S. (2013). *Apple orchard pruning residues as a potential bioenergy source in South Tyrol: a LCA case study*, 15th International Conference RAMIRAN 2013, 3-5 June 2013,Versailles, France.

Cherubini, F.; Bird, N.D.; Cowie, A.; Jungmeier, G.; Schlamadinger, B. and Woess-Gallasch, S. (2009). *Energy- and greenhouse gas-bases LCA of biofuel and bioenergy systems: key issues, ranges and recommendations.* Resources, Conservation and Recycling 53, 434-447.

Dyjakon, A.; den Boer, J.; Bukowski, P. (2014) *Europruning – a new direction for energy production from biomass. Agricultural Engineering, 3*(151), 29-40.

European Commission Directorate for Research & Innovation (2012). *FP7-KBBE-2012-6-singlestage Grant Agreement Number 312078 Europruning - Development and implementation of a new, and non existent, logistic chain on biomass from pruning*. Annex I – "Description of Work".
Guinée, J.B. (Ed.) (2002). *Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards*. Series: Eco-efficiency in industry and science. Kluwer Academic Publishers. Dordrecht.
Hertwich, E.G.; and Hammitt, J.K. (2001). A Decision-Analytic framework for Impact Assessment Part 2: Midpoints, Endpoints and Criteria for Method Development. In: International Journal of LCA 6 (1), 5-12.
ISO (2006a). *International Standard 14040:2006 Environmental Management – Life cycle assessment – Principles and framework.* International Organisation for Standardisation (ISO), Geneva.
ISO (2006b). *International Standard 14044:2006 Environmental management – Life cycle assessment – Requirements and guidelines*. International Organisation for Standardisation (ISO), Geneva.
Joint Research Centre (2011). *International Reference Life Cycle Data System (ILCD) Handbook-Recommendations for Life Cycle Impact Assessment in the European context.* First edition November 2011. EUR 24571 EN. Luxemburg. Publications Office of the European Union.
Jolliet, O.; Margni, M.; Charles, R.; Humbert, S.; Payet, J.; Rebitzer, G. and Rosenbaum, R. (2003). IMPACT 2002+: a new life cycle impact assessment methodology. *International Journal of LCA 8*(6), 324-330.
Milá, I.; Canals, L.; Romanyá, J.; Cowell S.J. (2007). Method for assessing impacts on life support functions (LSF) related to the use of "fertile land" in Life Cycle Assessment (LCA). *Journal of Cleaner Production 15*, 1426-1440.
Picchi, G.; Silvestri, S. and Cristoforetti A. (2013). *Vineyard residues as a fuel for domestic boilers in Trento Province (Italy): Comparison to wood chips and means of polluting emissions control.* Fuel, Volume 113, November 2013, Pages 43-49, ISSN 0016-2361, http://dx.doi.org/10.1016/j.fuel.2013.05.058
Udo de Haes, H.A.; Lindeijer, E. (2002). *Areas of Protection,* Second Draft, December 22, 2000. In: Gate to EHS: global LCA village, March 2002, 1-5.

OKREŚLENIE WPŁYWU NOWEGO ŁAŃCUCHA LOGISTYCZNEGO BIOMASY NA ŚRODOWISKO NATURALNE

Streszczenie. Odpady rolnicze (ścinki gałęzi) pochodzące z winnic i sadów stanowią duży potencjał jako odnawialne źródło energii. W artykule przedstawiono cel projektu EuroPruning, jakim jest przekształcenie tego typu odpadów w wartościowe paliwo na europejskim rynku energetycznym poprzez poprawę i rozwój technologii ich pozyskiwania, zbioru, transportu i magazynowania. Aby określić środowiskowe konsekwencje opisanej strategii wykorzystania ścinek gałęzi z drzew owocowych do celów energetycznych, zaproponowano metodologię opierającą się na tzw. analizie cyklu życia. Do analizy przyjęto różne warianty, które zostaną porównane z aktualnymi sposobami zagospodarowania gałęzi z drzew owocowych (spalanie na uboczu, rozdrabnianie i pozostawianie na miejscu, wykorzystanie w domowych systemach grzewczych). Omówiono zagadnienia związane z analizą cyklu życia oraz problematykę wyboru odpowiednich założeń przy przyjętej ocenie środowiskowej.

Słowa kluczowe: ocena cyklu życia, wpływ na środowisko, biomasa z sadów, energia z biomasy, ścinki gałęzi