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CARBON FOOTPRINT OF THERMAL ENERGY PRODUCTION FROM POPLAR SHORT-ROTATION COPPICE PLANTATIONS

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RESEARCH PURPOSES

- Evaluation of the carbon footprint generated in a small-scale wood-energy supply chain based on poplar short-rotation coppice plantations

- Comparison of the CO_2 emissions by the entire energy chain on a small scale up to the production of heat with a biomass boiler versus a conventional diesel boiler to generate the same thermal energy

METHODS

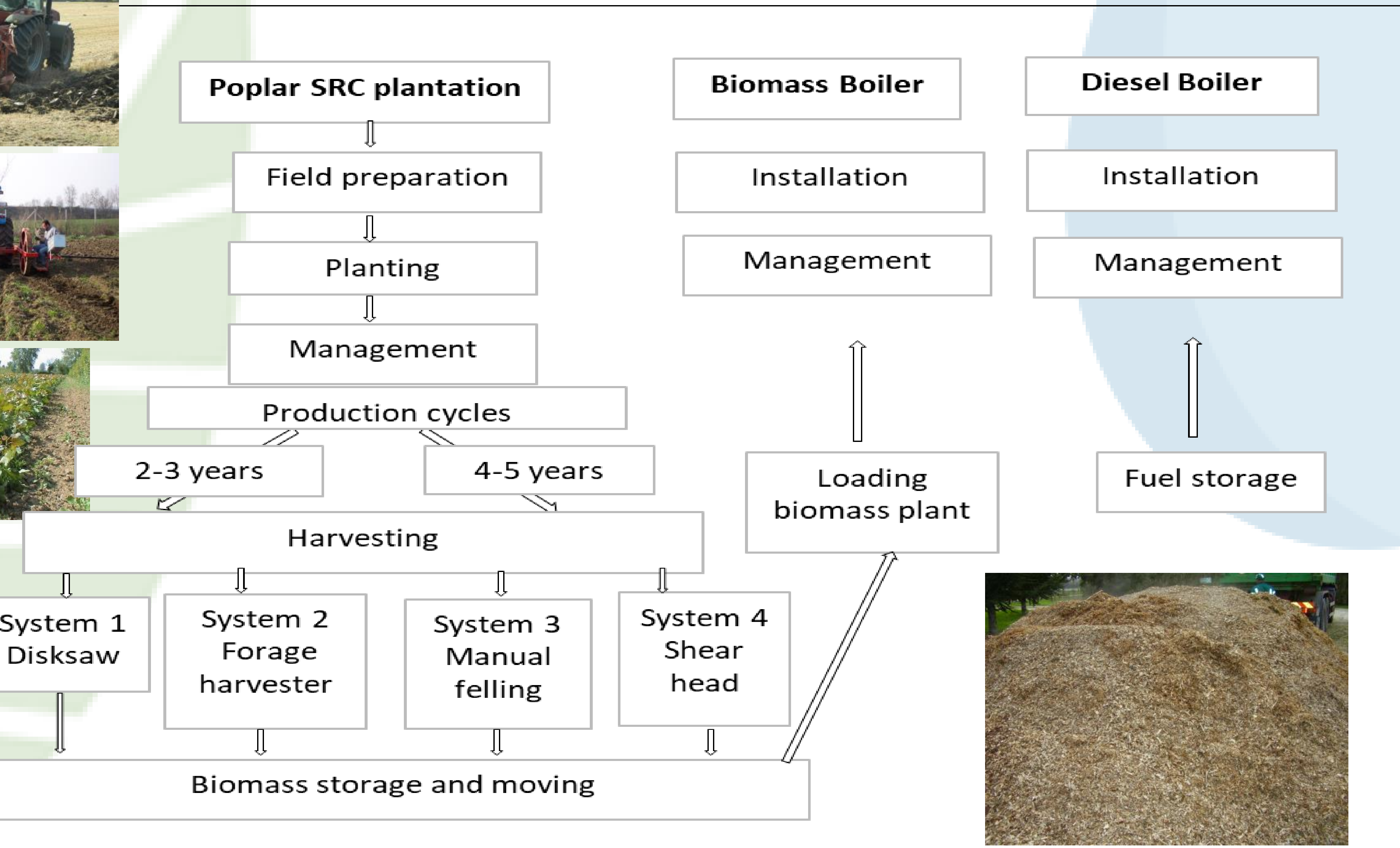
Study area: North-East of Rome (Central Italy), surrounding a biomass plant of the CREA farm.

- Application of the Life Cycle Assessment (LCA) to determine and compare the environmental impact in terms of carbon footprint generated to produce thermal energy by poplar biomass or diesel

- Scenarios examined for the poplar plantations
  - ✓ 4 cutting cycles
  - ✓ 4 harvesting system

- Biomass plant
  - ✓ Thermal power: 350 kW
  - ✓ Annual woodchips consumption: 290 Mg (w% 35)
  - ✓ Annual heating period: 130 days

Poplar energy supply chain boundaries



Scenarios examined

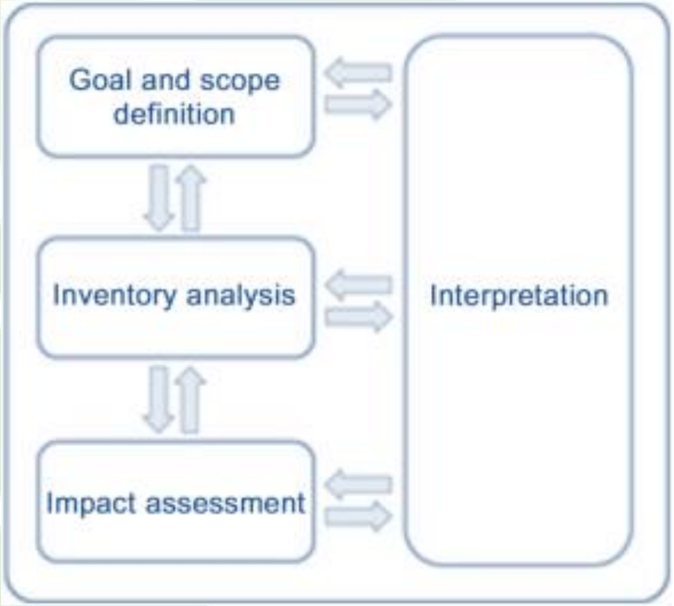
<u>Cutting cycles and Harvesting systems</u>

- 2- and 3-years cutting cycles (n. 8 and 5 cutting on a 16- and 15-years period, respectively):
  - ✓ TBHS - two-steps tractor-based harvesting system (a);
  - ✓ FBHS - one-step forage-based harvesting system (b).

- 4- and 5-years cutting cycle(n. 4 and 3 cutting on a 16- and 15-years period, respectively):
  - ✓ CSHS - Chainsaw based harvesting system (c);
  - ✓ SBHS - Shear head based harvesting system (d).

LCA Method

Life Cycle Assessment (LCA) is a method of environmental analysis, based on the calculation of specific indicators, which allows to evaluate the environmental effects of a product, production process or service "from cradle to grave", i.e. from the production of the raw materials used to the final use of the product and its disposal.



Scope of the study: Carbon footprint assessment of the Poplar short and medium rotation forestry to produce 1GJ of thermal energy.

System boundaries: from the soil tillage to the woodchip combustion in biomass boiler of 350 kWt.

Functional units: 1 GJ of thermal energy .

Environmental assessment method: Global Worming Potential (GWP) based on the IPCC 2007 - 100 years time horizon (IPCC GWP 100a).

Inventory analysis

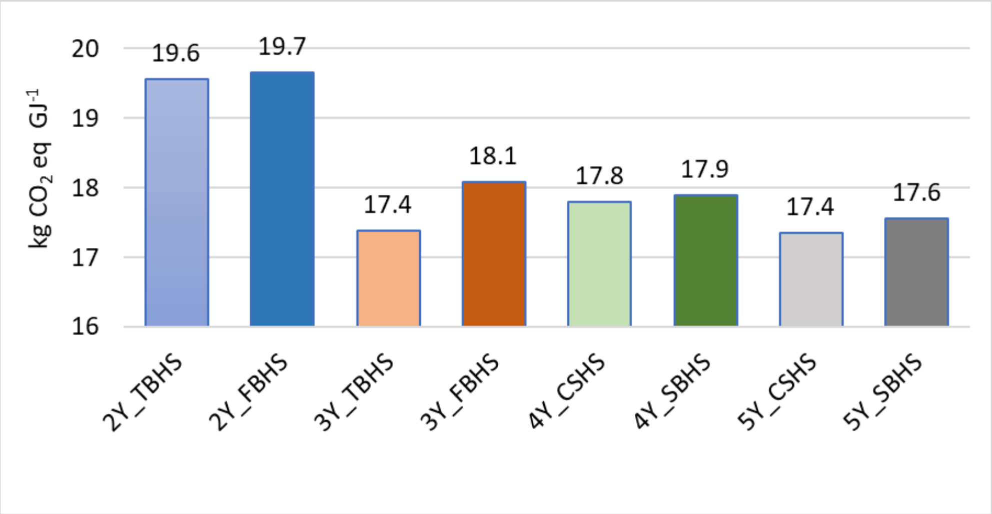
Primary data used: machine and equipment used characteristics (engine power, machine weights, hours of work performed, fuel and lubricant consumption)

Secondary data used: emissions of exhausted gases generated by the tractors, indirect emissions generated by the materials used for the constructions of the agricultural equipment and boiler (SimaPro 8.0.1 code, Ecoinvent 3 dataset), direct and indirect emissions of fertilizers and agrochemicals used (EFE-So software and PestLCI 2.0 mod.)

SOC as carbon sink: a theoretical 7.61 Mg C ha^{-1} (27,9 Mg CO_2 ha^{-1}) was assessed but not accounted in the study (only indicated in the discussions).

RESULTS AND DISCUSSION

Carbon footprint emissions per GJ



kg CO_2eq emitted per GJ of thermal energy produced in relation to the eight scenarios considered (IPCC GWP 100a).

- The various scenarios did not show significant differences, except for the 2-year cycle.

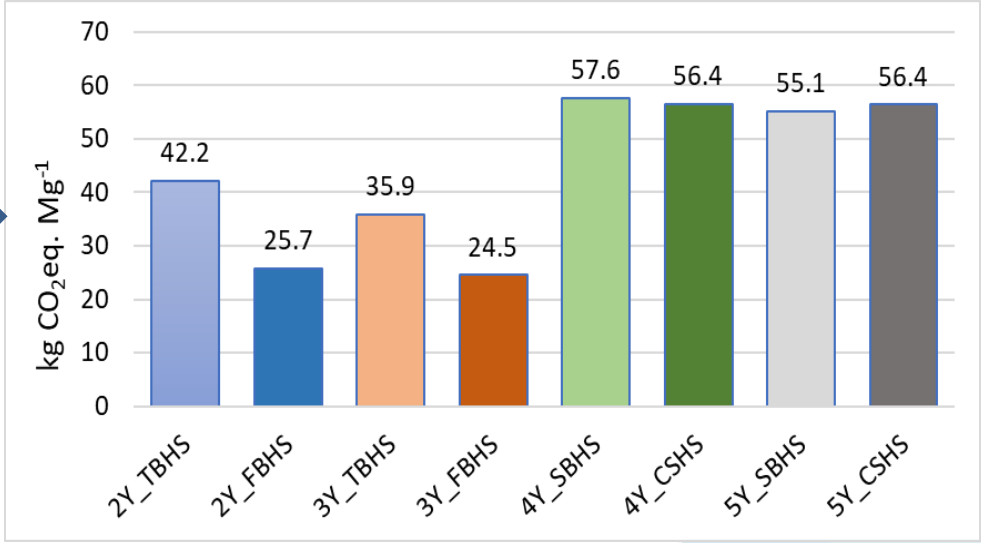
- In the 2-year cycle the higher emissions are due to the more frequent harvesting interventions (n. 8) and greater impact of the fertilization (49% of the overall emissions).

- In all scenarios the emissions are slightly higher for harvesting conducted with a higher level of mechanization.

- In the 5-year cycle the lower emissions are very affected by the reduced contribution of nitrogen fertilizers made only after each harvest.

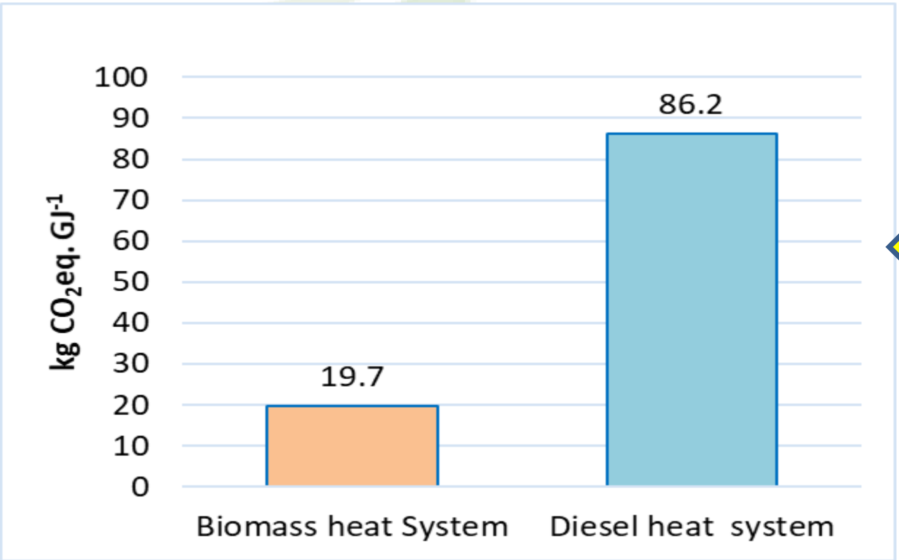
Carbon footprint emissions per Mg_{dm} in the Harvesting operation

kg CO_2eq emitted per Mg_{dm} of wood chip produced by the eight scenarios, considering the storage losses, and excluding the emissions of all the other agricultural practices (IPCC GWP 100a).



- The differences are mainly evident between the 2- and 3-year cycle, on the one hand, and the 4- and 5-year cycle, on the other.
- In the 2- and 3-year cycles, FBHS produces lower emissions, as it has a much higher work productivity than TBHS, and performs the harvesting operation in a single phase to produce wood chips, unlike TBHS which has 3 phases.
- The difference between 2- and 3-year and 4- and 5-year cycles is mainly due to the higher work productivity obtained from FBHS and TBHS compared to SBHS and CSHS, which resulted in less work time per Mg of biomass produced.

Carbon footprint in the two heat systems



Comparison of the emissions generated by a biomass boiler fueled with wood chips produced by the biennial poplar supply chain with FBHS (less efficient), and a diesel fueled boiler, to produce 1 GJ of thermal energy.

- The result of the study indicates a 77% reduction in greenhouse gas emissions in Biomass heat system compared to the emissions of the diesel heat system

- The carbon immobilized in the soil is not considered in the calculation. On the other hand, if we also consider this element (approximately 13.4 kg of CO_2 saved per GJ produced), the emission would be only 6.3 kg of CO_2eq, equal to 7.3% of those of the diesel heat system

CONCLUSIONS

The production of thermal energy generated by three-year and five-year poplar wood chips, which used the TBHS and CSHS harvesting systems, were more sustainable than the other production chains, even if the most marked difference can only be observed between the biennial supply chains and those of the other cutting cycles.

The type and quantity of fertilizer applied per unit of surface plays a fundamental role in environmental performance and for this particular attention should be paid to the optimization of the inputs used.

The most sustainable harvesting method is the one that involves fewer production steps. For this reason, the direct chipping of the plants in the field (FBHS) was more sustainable than the three-phases harvesting (TBHS, CSHS and SBHS) although, involving greater losses of dry matter during the storage phase, the advantage in terms of emissions is not very evident if the entire supply chain is evaluated.

The production of thermal energy generated by a biomass boiler compared to a fossil fuel one can allow a reduction of greenhouse gas emissions by 77%. This result can be further improved if we consider the CO_2 stored in the soil in the form of SOC at the end of its life cycle, with a reduction of emissions by 93%. In fact, CO_2 fixation in agricultural soil is the key point that should be analyzed in more depth and that make the bioenergy supply chain more sustainable.