

## **Life Cycle Assessment (LCA) of traditional charcoal production in Madagascar**

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### **Novelty**

Very few environmental assessments have been carried out on charcoal, especially concerning traditional production chains by earth mound kilns. This study produced a comprehensive LCA on this current charcoal production in Madagascar, compared with a prospective and more industrial production.

### **Context and scope**

Although charcoal is a very old source of energy, it is still widely used and even the main domestic fuel available in some regions, such as sub-Saharan Africa. In this context, the current situation of charcoal makers in Madagascar, related to the charcoal supply to the city of Mahajanga, was selected as the baseline study to conduct a comparison between two different production chains: the carbonization made by earth mound kilns, and by industrial kilns, with incineration of the pyrolysis vapours.

### **Material and methods**

LCA framework has been used to evaluate the relative environmental performances of the considered carbonization chains. Processes were modelled in SimaPro® software, using, when appropriate, the ecoinvent database. Nine impact categories, covering global, regional and local issues, were assessed by a combination of ReCiPe and IMPACT 2002+ methods.

System boundaries included all processes from biomass collection to charcoal delivery in Mahajanga. The chosen functional unit was the energy content of the delivered charcoal, based on its lower heating value. The biomass and charcoal supply chains were described according to the results from the European project CARAMCODEC.

Previous studies found that the carbonization process played a crucial role in environmental assessments, so a specific literature review on pyrolysis vapours was carried out. It revealed important technical difficulties for earth mound kilns monitoring and a lack of available data. Data from literature were then completed with a data collection from CIRAD experience since the 90s, and three data sets were finally distinguished: specific earth mound kiln data and more general data from partial combustion processes for the traditional carbonization chain, and specific data from industrial kilns with incineration for the prospective scenario. The corresponding data processing allowed considering uncertainties from experimental results and a Monte Carlo analysis was carried out to integrate them into the LCA results. Mineral coal production in Europe was also integrated as a reference scenario.

### **Results and discussion**

LCA results showed that carbonization made by industrial kiln is less harmful to the environment concerning local impacts and climate change, due to the incineration implementation. Carbonization by earth mound kiln was found to be more efficient for ozone depletion, metal and fossil depletion, terrestrial acidification and marine eutrophication due to lesser needs for infrastructures and biomass transport. No differences were identified for

freshwater ecotoxicity, carcinogens and respiratory inorganics, because of the uncertainties associated with the collected data and the impact assessment methods.

Potential future improvements of this work concern the addition of the impacts related to the domestic charcoal use in Mahajanga, and the development of additional prospective scenarios, especially with a biomass collection based on forestry plantations. More general methodological improvements of the LCA framework are also key issues for the overall quality of this specific assessment since pressures on the Madagascan forest could not be assessed, due to insufficient development of biotic depletion and land use indicators.