# Life cycle assessment of Graphene transparent electrodes

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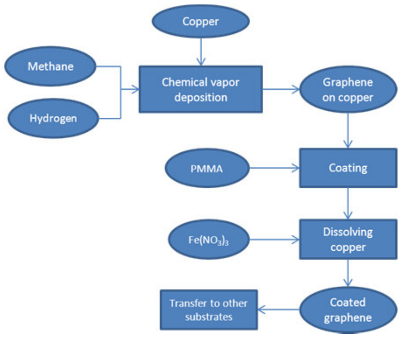
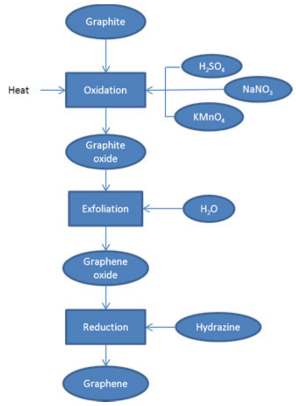
A lot of research is currently being performed on the topic of graphene, a single layered graphite material, since its discovery by Geim and Novoselov in 2004. One of the most promising applications of graphene is its use as a transparent electrode in electronics for the information and communication technology (ICT) industry as a replacement for indium tin oxide (ITO) because of its properties of high conductivity and transparency.

In this study, an environmental assessment is performed of graphene transparent electrodes in comparison with conventional electrodes made from indium tin oxide (ITO). The analysis focused on impact on human health, impact on the natural environment and impact on exhaustible resources.

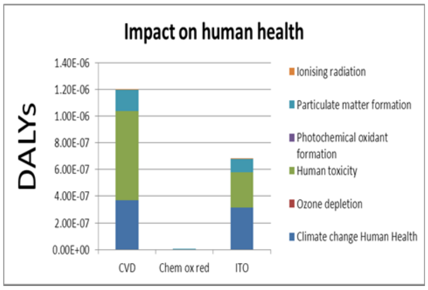



Flowchart of Chemical Vapor Deposition

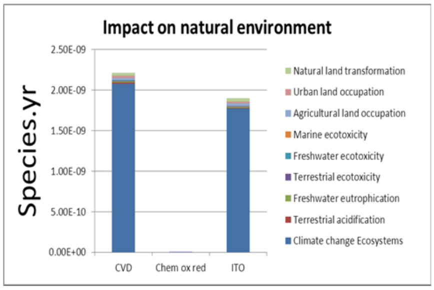
**Functional unit:**
"transparent conductor material for 1000 units of a transparent electrode, each having a geometric surface area of 1 cm$^2$, a sheet resistance of <100 ohm/square and an optical transmittance of >90%"



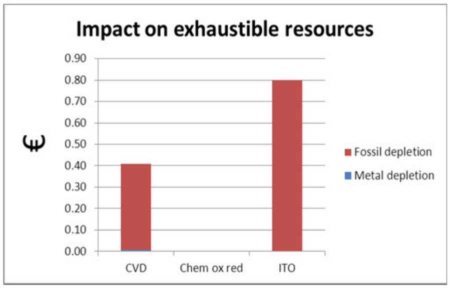

Flowchart of Chemical Oxidation and Reduction




**Impacts on human health (per f.u.).** Impacts on human health are mainly caused by impacts on human toxicity and impacts on climate change. CVD impacts on human toxicity are mainly caused by the copper demand and CVD impacts on climate change are mainly caused by the iron nitrate demand. Impacts from chemical oxidation and reduction are mainly due to the effects on climate change and particulate matter formation because of the oxidation of graphite (mainly due to the sulfuric acid demand).




**Impacts on natural environment (per f.u.).** Impacts on natural environment are mainly caused by the impacts on climate change for all three production routes. For CVD this is mainly caused by the iron nitrate production, for chemical oxidation and reduction mainly by the oxidation of graphite (mainly caused by the sulfuric acid demand and potassium permanganate demand).




**Impacts on exhaustible resources (per f.u.).** Impacts on exhaustible resources are mainly due to the fossil depletion. Metal depletion is negligible. For CVD this is mainly caused by the iron nitrate demand, for chemical oxidation and reduction mainly by the oxidation of graphite (mainly due to sulfuric acid demand and potassium permanganate demand).

**Discussion and conclusions:** Although there are major uncertainties in the data and there is much contradicting information within the literature, there are multiple studies emphasizing the potential of the material. There is a high interest because of the wide range of applications (in electronics) and because of the scarcity of the ITO material. Chemical Vapour Deposition (CVD) yields graphene that is of the highest quality (high sheet resistance and high optical transparency). Complicating factor for graphene produced by CVD is the electricity requirement. The impacts of Chemical Oxidation and Reduction are the lowest, but the quality of this production route is of concern. Although some studies report promising results, there are major contradictions in current literature. Further research is recommended to increase the consensus among current studies and to reduce the uncertainties.