# Graphene and graphene derivatives for energy applications

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**Abstract**
Graphene has several unique properties potentially useful for a range of energy related applications. Established and potential applications include batteries and supercapacitors, solar cells, gas sensors, gas storage, nuclear industry and applications in high voltage transfer cables. These will be reviewed and illustrated with examples from recent reports.

Batteries is a high growth market where graphene's electric and thermal conductivity obviously is useful, but more interesting is graphene's potential as an agent to stabilize certain meta-stable phases, e.g. in sulfur based cathodes for post-LIB-batteries, pursued by a range of battery companies. Graphene based super capacitors have already been commercialized. For SCs, the organization of the graphene particles is important. The material must be densely packed to reduce the volumetric capacity but still having a sufficiently open structure to allow fast migration of ions. Applications for photovoltaics are less obvious, due to the black color of graphene and its lack of band-gap in its pure form. However, doping of graphene has been shown to create band-gap, and compounding with other electronic materials such as zink oxide also shows potential. In fuel cells, graphene may play a role as support for catalysts and in proton exchange membranes in DMFCs.

The use of GO to soak up heavy radionuclides from water has been reported and verified[1]. This is certainly one of the applications to be seen commercialized in this decade, easily requiring production of hundreds of tons of GO per year. On the other hand, applications as components in sensors, although potentially large in numbers will be small in mass due to the very limited amount used in each sensor. When it comes to energy storage, GO being an insulationg material does not have an obvious role. However, GO can easily be converted to reduced graphene oxide (rGO), effectively competing with other graphene powders. Effectively, rGO has the advantage over other graphene powders in that GO is easy to work with. rGO has a high density of defects compared to more well-crystalline graphene types, but this can also represent an advantage in that holes present in the sheets allowing for diffusion of e.g. Li-ions.

For most energy related applications, the useful form of graphene is powder. Abalonyx is active in production of GO and rGO as well as in the development of GO and rGO optimized for several applications. Abalonyx' sister company Graphene Batteries is engaged in application of rGO and pillared rGO for certain battery and supercapacitor applications with promising results.

The final, and not least important parameter for large scale use of graphene family materials is price. Graphene powders produced in plasma are expensive and the process not very scalable. Delamination of graphite in organic solvents has similar challenges. Present estimates indicate that the price of GO can come down to well below 40 USD/Kg and rGO to just under 100 USD/Kg – price levels that can be tolerated by many industries if compensated by real improvements in performance of the GO/rGO-containing products.

## References

[1] Romanchuk Anna Yu. , A. S. (2013). *Phys. Chemistry*, 21, 15, 7 (2013) 2321 - 7.