

# Graphene Ultracapacitors - the Skeleton of Electric & Hybrid Power Systems

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## **Abstract**

Skeleton Technologies as a company and our success in the energy storage industry are based on heavy emphasis on R&D on what we call “curved graphene”, a patented nanoporous carbide-derived carbon, which allows to create hexagonal one-layer graphene structured inside the carbon electrode. The patented synthesis process allows to finely engineer the pore size and distribution which guarantees a very large surface area of 2000 m<sup>2</sup>/g, but more importantly a perfect match between the electrolyte ions and carbon pore sizes. This ensures that the whole material “works” and allows for higher capacitance, but also lower internal resistance and higher electrochemical stability. Developing curved graphene has been an on-going process ever since and advancements made in its properties have directly translated to generations of SkelCap ultracapacitor cells with increasingly higher energy and power densities. Up-to-date company has invested USD 30 M for development and manufacturing ramp-up, allowing it to reach commercial scale and build a strong customer base ranging from German Tier1 automotives to the European Space Agency.

Skeleton Technologies has solved the industrial implementation challenge facing all graphene material companies by forward integration. Curved graphene has provided Skeleton Technologies' ultracapacitors with an unmatched competitive advantage: our ultracapacitors deliver twice and energy density and four times the power density compared to competing products. Developing of proprietary technology in the full value chain from ultracapacitor electrodes, cell, modules and energy storage system has allowed this advantage to directly carry to our customers and their applications, providing significant energy savings across industries including automotive, heavy transportation, maritime, renewable energy, energy production and storage, and aerospace.

The automotive sector uses ultracapacitors in start-stop systems, regenerative braking, voltage support units and electric turbochargers, where our SkelCap cells offer a huge weight, volume, and cost advantage compared to our closest competitor, not to mention a higher power density. A 5,7 kW SkelCap cell weighs 178g and has a volume of 0.124 litres. Maxwell cells, the current market leader, offer only 5.5 kW of power in a cell that weighs 510g and has a volume of 0.4 litres. We can offer more power with a cell that is three times smaller and lighter.

We are the only manufacturer that can offer hybrid electric busses with the technology to reliably operate in hot climates. Due to higher efficiency Skeleton cells generate less heat from charge/discharge cycles enabling hybrid electric busses to operate on both sides of the equator.

The future of renewable energy is very much tied to the technological developments in the energy storage sector. Our SkelGrid 2,5 MW Pulse Power Supply container can be used to stabilize the grid in times of peak consumption and lows of production. To reach 2,5 MW, only 1250 SkelCap SCA3200 cells are needed, compared to nearly 2600 of competing cells with same weight and volume needed to reach the same amount of power.

Lastly, full energy storage solutions are the key to unlocking graphene ultracapacitor potential, Firstly, Skeleton has been successful in reducing fuel consumption of trucks by up to 25%. Successful road trials for a ultracapacitor based KERS have been carried out and the company is currently expanding the program. Secondly, Skeleton has successfully hybridized diesel-based port cranes, which allows to reach up to 40% cost savings for the customer. RTG port cranes equipped with Skeleton Technologies' full energy storage system. Both markets represent a significant opportunity, which can only be addressed with a full energy storage system.

Curved graphene is a competitive advantage our competitors have no answer to. That doesn't mean we are done, though. Skeleton Technologies is just getting started and we are constantly working on improving our technology to help our customers save more energy.

## **References**

## **Figures**