Ships are a relatively fuel-efficient means of moving bulk cargo: for equivalent weights and distances, carbon dioxide emissions from shipping are considerably lower than air freight and road transport. At its best, emissions from shipping also undercut rail transport. This can be used as a rough proxy for transport costs and helps to illustrate the crucial role of international shipping in supporting global commerce, carrying as it does an estimated 90% of world trade. The volumes are huge: for containerised cargo alone, the equivalent of 114 million twenty-foot containers was shipped worldwide in 2010.

It is these quantities that make shipping such a significant contributor to greenhouse gas emissions, accounting for almost 3% of total man-made carbon dioxide emissions in 2007, according to the latest comprehensive study by the International Maritime Association (IMO) – and CO₂ emissions from ships are projected to more than double by 2050. International shipping is currently not subject to any form of regulation on CO₂ emissions, in large part due to the difficulty in assigning (and monitoring) these. The IMO is working towards global agreements on CO₂ – so far it has achieved an energy efficiency standard for new ships from 2015 – but progress is slow, leading to threats from the European Union to impose its own limits within its waters.

But air pollution is as much a concern as GHG emissions. While a country may impose strict limits on the quantities of pollutants that can be emitted by road transport, necessitating the use of catalytic converters on vehicle exhausts, its harbours will host ships for which limits are much looser. Most ships use cheap, heavy fuel oils with high levels of impurities and their exhaust is laden with sulphur dioxide (SO₂), particulate matter, and nitrogen oxides (NOₓ). Even ships burning cleaner diesel fractions may emit more than necessary due to a lack of exhaust aftertreatment.
Ships number in the tens of thousands, so how severe can the effect on air quality really be? A 2009 study by NOAA and the University of Colorado found that “globally, commercial ships emit almost half as much particulate matter pollutants into the air as the total amount released by the world’s cars”, with much of this close to shore. However, regulatory limits on these pollutants are becoming progressively tighter, with certain Emissions Control Areas deemed especially sensitive and subject to a higher level of protection.

Something of a revolution in shipping is needed. While obviously much can be accomplished by fairly simple measures, some shipbuilders and operators are leap-frogging this gradual evolution with more daring concepts and even proposing fully ‘zero-emission’ ships. So is it possible that fuel cells have a role to play in international shipping?

The European Commission FCSHIP study concluded in 2004 that the use of fuel cells in ships was feasible, with the usual caveats about availability and fuel supply. The subsequent METHAPU project set out to evaluate solid oxide fuel cell technology running on methanol for ship auxiliary power: a 20 kW fuel cell system from Finnish company Wärtsilä was installed on the deck of the car carrier MV Undine, owned and operated by Wallenius Wilhelmsen Logistics. The 2009/2010 trial showed that the use of fuel cell technology and an alternative fuel poses no more of a risk to a commercial vessel than conventional equipment and fuel, laying the foundation for further deployment. Wallenius has published a roadmap to emission-free ships for its future fleet, with fuel cell APU included from 2030.

The FellowSHIP project has tested fuel cell technology integrated with a ship’s propulsion system. Eidesvik Offshore ASA is a specialised fleet operator working in supply, subsea operations, seismic surveying and cable installation; it has a progressive environmental policy and introduced the first gas-fuelled supply ship in 2003. There are now several LNG-fuelled ships in its fleet, among them the Viking Lady (photo, top). The gas–electric propulsion system of the Viking Lady facilitated the installation, in September 2009, of a 330 kW molten carbonate fuel cell from MTU Onsite Energy, without the need for pre-reforming. During the trial, the fuel cell logged 18,500 successful operating hours, providing supplementary power to the ship at an electrical efficiency of over 52% at full load. The next phase of FellowSHIP, now underway, is installing a battery pack for energy storage to create a true hybrid propulsion system for the Viking Lady.

Eidesvik operates in the Baltic and North Seas. These are both Emissions Control Areas where limits are due to become much stricter in January 2015, so it is not surprising that there is interest in adopting liquefied natural gas (LNG) for shipping in this area – there is a strong business case for doing so. These ships would be ‘fuel-cell-ready’ from a fuel supply point of view. In a recent interview with The Maritime Executive Magazine, Professor Zuomin Dong of the University of Victoria, Canada, who has conducted extensive research into hybrid electric and fuel cell propulsion for vehicles and ships, predicted that “LNG-fuelled engines could become the stepping stone for the wide adoption of LNG-fuelled fuel cells as prime movers” for ships. The driver for adoption would be the greater fuel efficiency of fuel cells, but he expects a lengthy transition period via diesel–electric propulsion and/or fuel cell APU.

Hornblower Cruises & Events, having already embarked on the diesel–electric path with a hybrid ferry in San Francisco Bay, has taken another step forward by incorporating a hydrogen fuel cell into its newest hybrid ferry. The 600-passenger Hornblower Hybrid ferry operating in New York harbour has a power management system that allows the captain to switch power sources as required and combines diesel engines, solar panels, wind turbines and a 32 kW PEM fuel cell from Hydrogenics (hydrogen is stored in an on-board tank).
But ferries, even large ones, aren’t cargo ships, so are they a worthwhile target for emissions reductions? Scandlines certainly thinks so. It operates a number of ferries in the Baltic Sea; for the 18.5 km crossing between Denmark and Germany over the Fehmarn Belt, a ferry launches from each harbour every 30 minutes, around the clock and throughout the year. Each crossing consumes almost a ton of fuel oil and emits almost three tons of CO\textsubscript{2}. That’s over 100,000 tons of CO\textsubscript{2} emitted annually for just this route, along with almost 3,000 tons of SO\textsubscript{x} and NO\textsubscript{x}. To remain competitive, Scandlines needs to find an alternative and it wants that alternative to be zero-emission.

FutureShip, a subsidiary of Germanischer Lloyd, has developed a concept for Scandlines (below) that uses fuel cells as the primary source of propulsion: 8.3 MW fuel cells draw fuel from 140 m\textsuperscript{3} hydrogen tanks, sufficient for a passage of 48 hours at 17 knots. To be truly zero-emission, the idea is to use excess wind energy in Denmark and Germany to renewably produce hydrogen. The most exciting aspect of this design is that FutureShip says it could be implemented on the Baltic ferries within the next five years, as it uses existing technology and the ferries would cost only about 25\% more to build than a conventional design.

A number of small ferries and boats have already shown the benefits of having fuel cells on board. Although we may have to wait a few years, it seems probable that fuel cells are also a serious prospect in larger ocean-going vessels.