Making the case for nuclear power in shipping

Professor Jan Emblemsvåg of the Norwegian University of Science and Technology recently spoke at the Gard Summer Seminar "Making Waves – geopolitics, energy and the future of shipping." He is a knowledgeable and outspoken proponent of nuclear power for vessel propulsion and made a strong case for including nuclear reactors in the mix of alternative fuels to power the green transition.

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Upscaling of green fuels may be unrealistic

Green ammonia is often presented as a solution to decarbonize shipping and large transporters. There is a slight problem, though: volume and energy density.

The large container ships (larger than 10.000 TEUs) exemplify the situation. In 2020, about 580 such large container ships sailed the seas, and they typically consume 250 – 350 tons Heavy Fuel Oil (HFO) every day. This equals an average energy requirement of 3,350 MWh per day since a tonne of HFO has a thermal value of 11.2 MWh/tonne. As ammonia has a thermal value of 5.2 MWh/tonne, such a ship requires about twice as much green ammonia as HFO in terms of volume.

Green ammonia requires electrolysis, and somewhere between 9 – 15 MWh per tonne is required. Using the center point, we find that to replace 1 TWh thermal energy in shipping, 2.2 TWh of electric energy is required when using green ammonia. The annual global marine fuel consumption is about 300 million tonnes annually. Using the same calculation, the amount of electricity required is 7,778 TWh/yr, or almost 2.7 times the total EU electricity production in 2021 (2,888 TWh/yr).

For context, the total greenhouse gas emissions from the marine industry are about 3% of the total global emissions. This amounts to just over the emissions of Germany as a whole country. Indeed, without any effective countermeasures, international shipping is expected to reach 10 – 13% of global emissions within a few decades.

Clearly, the case for decarbonization of shipping is not only very demanding but also highly unrealistic with today's path. Fresh thinking is required.

Shipping going nuclear

The nuclear option comes on the table simply by energy density. Natural uranium contains 3 million times more energy than coal, and thorium contains 3.5 million times more energy than coal. The green transition is all about power/energy density, which Vaclav Smil notes has always been the historical trend in the past. The only difference this time, is that we must avoid emissions. By going nuclear there are no emissions since the process is fission and not combustion. Another upside to nuclear is availability of materials. An EU report from 2020 details the riskiness of today's energy policy due to the limited availability of materials for both renewable energy and electric vehicles. Uranium, however, can be extracted directly from seawater in vast quantities at reasonable costs.

Finally, nuclear provides a cost advantage. In my own research, I have demonstrated that for an Aframax tanker operating between Singapore and the Persian Gulf, the nuclear option can in fact cut costs compared to HFO. Nuclear also has the capability of providing synthetic fuel at competitive levels. At the nuclear power plant Nine-Mile-Point in the USA, the target is to produce hydrogen at 1 USD/kg within 10 years, which is actually cheaper than hydrogen from most fossil energy sources today which operate at 0.7-1.6 USD/kg! Competing technologies are expected to reach 1,5 USD/kg at best.

Why it didn't work before

The question about nuclear in the past and why it has not made it into commercial shipping by now, is a very valid question. Indeed, three nuclear-powered merchant vessels have been constructed decades ago, but they all succumbed to costs. The key difference now, however, is the reactor design.

All past nuclear-powered vessels, including military, have used a Light-Water Reactor (LWR) of some sort. These reactors use uranium as fuel and water as coolant. To provide maximum thermal efficiencies they are pressurized. Pressurization introduces an explosion risk (true for any pressurized system, not only nuclear), and to counter this risk numerous safety mechanisms are introduced. Hence, the reactors are completely safe, but the additional safety costs money. Also, water has low thermal density compared to other coolants now being suggested such as liquid lead and molten salt. This makes it harder to design small LWRs with as high output as those using alternative coolants. Therefore, the use of a LWR requires a certain size to be cost competitive. However, modularization and industrialization has improved this situation – also for other types of reactors.

Another perspective to keep in mind is that the new reactor designs are inherently safer than those in the past. This not only makes the very notion of having nuclear reactors on merchant ships doable, but it also saves costs as the complexity of the entire reactor system can be simplified. This was exemplified by the work performed at Oak Ridge National Laboratory in the 60s and 70s where the so called Molten-Salt Reactor (MSR) outperformed the LWR or the Pressurized Water Reactor (PWR) type by almost 20% (both being less costly than coal power without carbon tax).

Also keep in mind that we now have technologies that were unheard of 30 – 50 years ago. The digital technologies of today allow more accurate and careful design of the reactors themselves, but also facilitate entirely new ways of collaboration. In the past, a nuclear ship would have to be completely self-sustained in terms of crew and their competence. Obviously, recruiting enough nuclear trained personnel to operate a nuclear ship, is a major task. Today, however, remote operation technologies enable a control center on land to handle multiple ships if something comes up that is outside the scope of the crew competence. Furthermore, modern manufacturing enables more effective production of most components, further cutting costs.

Thus, it is fair to say that the early, nuclear movers in merchant shipping were basically too early. Today, however, the time is right.

Why nuclear will work today

With the climate crisis now upon us, I think nuclear will have to be part of the solution. Machiavelli once said that "necessity is the mother of invention". The need is here, and the time is now.

The technology is now almost ready, and why wait to cut costs tomorrow when we can start today? Sure, some development remains, and some early movers are taking more risks than others. This is normal for all innovation regardless of industry. The most important is to realize that ramping up a new industry typically takes a generation. Therefore, perhaps it will take a couple of decades before the HFO will be displaced by the nuclear propulsion systems All nuclear technology takes time to achieve approval and operating licenses, and construction capacity and upskilling will also take a long time. All the more reason to start now.

Clearly, solving the fuel challenge for shipping takes time, but it is not that far into the future. It can come faster if we make the right decisions early and have enough funding to sustain the work, but it can also be delayed – like all innovation work – if mistakes are made and funding dries up. One thing is sure, if we succeed the potential is vast both in cutting emissions and solving the energy security issues, but also economically.

Like the late Ray Anderson, Chairman of President Clinton's Sustainability Council, said; "I want to do well by doing good". Sure, subsidies are probably needed initially, but to secure an energy transition we need something that is objectively better than the old solution, and modern nuclear has this potential.

Gard welcomes discussion of alternative fuels and technologies to tackle decarbonization of shipping. The views expressed by the author are his own. For more information about ongoing research on the potential for nuclear propulsion technology in shipping visit Jan Emblemsvåg - NTNU