TERRESTRIAL
ENERGY

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Professor May R. Berenbaum
Editor-in-Chief
Proceedings of the National Academy of Sciences

Subject: Correction of Factual Errors in PNAS Article "Nuclear waste from small modular reactors"

Dear Professor Berenbaum:

Terrestrial Energy is deeply disappointed in the poor quality of this article and its numerous and significant factual errors. The article in several instances implies that any single shortfall of any small modular (SMR) system is universal to other SMR designs. As such, the article fails to comply with the Academy's high standards.

The article's conclusion is the most egregious case in point:

> "Molten salt- and sodium-cooled SMRs will use highly corrosive and pyrophoric fuels and coolants that, following irradiation, will become highly radioactive."

Such a statement ignores well-established fact in the field: No reactor uses or proposes using pyrophoric fuels. While sodium reactors indeed have a pyrophoric coolant, the coolant does not become highly radioactive. However, the sentence clearly implies both molten salt and sodium cooled reactors have pyrophoric fuels and coolants, which is simply false. The article includes other numerous inaccuracies about Terrestrial's Integrated Molten Salt Reactor (IMSR). These inaccuracies include the following:

Table 2, for example, lists the IMSR's burnup to be 14 GWd/tonneHM and quotes a Terrestrial Energy paper as a source (REF 86). This implies more used fuel mass than current PWRs. However, the PNAS article ignores a key innovation noted in REF 86: the IMSR will obtain 31.9 GWd/tonneHM, burnup similar to current light water reactors. The authors, however, use a low-reference case in REF 86 for their comparison.

The article also incorrectly says the IMSR reactor material is the nickel alloy Hastelloy N. In addition, the article implies that in any smaller reactor more thermal neutrons will reach the reactor vessel and cause activation. This ignores the fact that thermal spectrum reactors like the IMSR provide numerous simple ways to limit thermal neutrons from reaching the vessel. The authors then quote a value of greater than 10^12 n/cm2-sec as the IMSR's thermal flux reaching the vessel; they conclude this will make the used vessel very radioactive. However, they reference a university paper (REF 29), whose authors clearly state they are unfamiliar with the IMSR design and that they merely made assumptions to do their modeling. Significantly, the design these authors reference had minimal reflectors and no absorbers like those included in the IMSR design. REF 29 also does not indicate thermal flux at their reactor vessel location. Notably, the IMSR's actual predicted thermal neutron flux at the reactor vessel is over 1,000 times lower. This is an immense difference, and this implies there is in fact minimal activation of IMSR reactor vessel material.

The article makes the false assumption that no SMR will reduce the amount of certain troublesome long-lived fission products per unit electrical output. The reality is that the IMSR features a thermal efficiency roughly 50% higher than comparable light water reactors. This means that the IMSR creates approximately 1/3 fewer isotopes, since less fission power is needed per unit energy output. The IMSR also features a very soft neutron spectrum and long fuel residency time. As a result, masses of plutonium and other transuranics in waste are much lower than those in light water designs per unit energy output. Ref 86 by Terrestrial Energy makes this point, which the authors also ignore.

The article implies that graphite wastes for the IMSR are unique. This ignores the entire field of gas-cooled, high-temperature reactors. These are good potential reactors for many reasons, though they would produce far more graphite waste and a greater volume of spent fuel than any of the limited systems the paper reviews. The IMSR gains great benefit from the use of graphite and will produce less graphite waste than other graphite-moderated designs. Terrestrial Energy had communicated to a National Academy of Sciences panel some of the conditioning methods that will aid with this area, but the paper does not mention these.

The article asserts that used molten salt fuel is unsuitable for the same geological disposal options the current light water reactor fleet would use. Generation IV systems have great overall advantages over the existing fleet; however, a different reactor will have different waste forms. Terrestrial Energy fully appreciates that a problem associated with the early deployment of light water reactors more than 50 years ago was the lack of focus on waste management. The authors, however, imply that Terrestrial Energy and other vendors are ignoring this issue.

To the contrary, Terrestrial Energy has presented material to the NAS that describes our efforts with ANSTO in Australia to use their Synroc technology. This approach will convert the IMSR's used fuel for long-term sequestration into a form more durable than that of current light water reactors. One of the PNAS article's authors, Dr. Allison MacFarlane, was on the NAS panel, and she specifically commended Terrestrial Energy's choice of Synroc for this purpose. The article, however, makes no mention of this option.

The article also fails to even acknowledge that most Generation IV systems like molten-salt and sodium-cooled reactors, also have great flexibility on the choice of fuel sources. Thus, the IMSR and other Generation IV systems in future and if policy supports can help reduce current stockpiles of spent nuclear fuel through the consumption of transuranic wastes. Among other Generation IV reactors, the IMSR is unique: It will use standard assay low-enriched uranium in a simple once-through fuel cycle. Among other benefits, the IMSR provides the future flexibility to help destroy or reduce current or future stockpiles of plutonium.

Terrestrial Energy is taking waste management very seriously. The approach these authors use is of serious concern. No industry takes such a full accountancy and responsibility for its entire waste stream as the nuclear energy industry. Waste volumes from all nuclear reactors are minute in comparison to other industries. Nations with power reactors, together with their institutions and reactor vendors, remain committed to safe, effective management and long-term storage of used fuel. The IMSR and other advanced reactors aim to supply the world with the clean and affordable energy it desperately needs. Safe, long-term management of long-lived radioactive materials is indeed achievable. In fact, this is a major goal of all Generation IV reactor technologies.

Regards,

David LeBlanc

David LeBlanc
Chief Technology Officer
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References:

29. J. P. Carter, R. A. Borrelli, Integral molten salt reactor neutron physics study using Monte Carlo N-particle code. Nucl. Eng. Des. 365, 110718 (2020).

86. J. Choe, M. Ivanova, D. LeBlanc, S. Mohaptra, R. Robinson, “Fuel cycle flexibility of terrestrial energy’s integral molten salt reactor (IMSR)” in 38th Annual Conference of the Canadian Nuclear Society and 42nd Annual CNS/CNA Student Conference (Canadian Nuclear Society, Toronto, Ontario, Canada, 2018), pp. 3–6.