Northern Europe Enclosed

Engineering a Solution to Sea Level Rise

Adapted from "NEED: The Northern European Enclosure Dam for if Climate Change Mitigation Fails," by **Sjoerd Groeskamp** [Royal Netherlands Institute for Sea Research (NIOZ), and Utrecht University] and **Joakim Kjellsson**. Published online in *BAMS*, July 2020. For the full, citable article, see [DOI:10.1175/BAMS-D-19-0145.1](https://doi.org/10.1175/BAMS-D-19-0145.1).

The global mean temperature is expected to rise 2.6°–3.1°C or more by 2100. Global-mean sea level rise (SLR) lags behind global-mean temperature rise, but is accelerating and has risen more than 21 cm since 1880. An SLR of 1–2 m is possible by 2100, and it is virtually certain that global-mean SLR will continue beyond 2100. The predicted baseline of 2.3-m global-mean SLR per 1°C suggests an unavoidable 5–11-m rise over the next centuries to millennia. At this rate, global-mean SLR may pose an unprecedented threat to society as we know it.

In case of a lack of effective response to the climate change threat, we propose the construction of a Northern European Enclosure

The proposed location of the Northern European Enclosure Dam (NEED), combined with areas where the population density exceeds 200 persons per square kilometer in the year 2020 (pink dots). These data provide the population within the enclosure residing in submerged areas for a certain amount of sea level rise (inset).

Dam (NEED) to disconnect the North and Baltic Seas from the Atlantic Ocean and protect 15 northern European countries from global-mean SLR. This can be achieved by constructing two enclosure dams. The southern part of NEED would connect France to the southwest coast of England and measures 161 km in length, with an average depth of about 85 m and a maximum depth of 102 m. The northern part of NEED would extend from the northeast tip of Scotland, via the Orkney and Shetland Islands, to Bergen in Norway. The northern part would be 476 km long and average 127 m deep, with a maximum depth of 321 m in the Norwegian Trench. The construction of NEED, one of the most challenging civil engineering feats ever attempted, would protect coastal communities currently with about 25 million people below projected 2-m SLR; 55 million people live below the projected 15-m SLR.

While we do not and cannot conclusively determine if NEED can and should be constructed, we can say that if immediate and enormous climate mitigation efforts are not undertaken, it is one of the best solutions for SLR in northern Europe, which is very concerning because it will have massive impact.

Alternative solutions can be categorized into 1) no action, 2) protection, or 3) managed retreat. Based on monetary value alone, the cost of no action will exceed that of protection

Circulation and tidal amplitude

△* The circulation and sea surface height (SSH) for a scenario (a) without and (b) with NEED. The SSH is assessed by taking the 95th percentile of the hourly SSH output from the numerical model run and is indicated by the blue colors (appendix C). Orange contours show the 0.2-, 2-, and 20-Sv contours of the barotropic stream-function ($1 \text{ Sv} = 10^6 \text{ m}^3 \text{ s}^{-1}$).

and managed retreat by a factor of 5–10. Additional nonmonetary losses such as social disruption will be such that we only consider protection and managed retreat as practical solutions and alternatives to NEED.

Technical considerations for constructing NEED

The part of NEED-north that would cross the Norwegian Trench with depths of more than 300 m would present a unique technical challenge. Furthermore, enclosing the North and Baltic Seas would yield a net freshwater discharge of $40,000 \text{ m}^3 \text{ s}^{-1}$ into the basin,

△* (left) The Saemangeum Seawall in South Korea and (right) the Afsluitdijk in the Netherlands, which are both more than 30 km long.

leading to a SLR of 0.9 m yr^{-1} within the enclosure that would need to be pumped out into the Atlantic Ocean. Otherwise, the discharge would decrease the salinity of the basin by a factor of 10 in about 100 years, affecting ecosystems, biodiversity, and fishing.

NEED would significantly impact the maritime industry. The busiest trading ports in Europe would lie within the enclosure, but sluice gates could allow shipping traffic. Alternatively, harbors could be built on the ocean side of NEED to facilitate the transfer of goods within the enclosure. Of course, there would be many negative effects due to SLR on the maritime industry without the protection afforded by NEED.

Financial feasibility of NEED

Based on the documented costs of projects such as the Saemangeon Seawall, the projected annual expense of NEED would be 0.07–0.16% of the combined gross domestic product (GDP) of the 15 involved countries over 20 years, numbers that would be easily achievable.

For example, the Netherlands already has about 3,600 km of hard and soft coastal protection; 4 million people currently live below sea level. This may be sustainable for 2–3 m of SLR, but if SLR exceeds 5 m, protection costs could reach 18 billion euros annually and exceed the cost of evacuation while reaching technical limitations. If SLR only reaches 1.5 m, protecting the Netherlands would cost only one-third as much as NEED. For more SLR, protection quickly becomes technically and financially challenging and possibly unsustainable. All things considered, we argue that integrated over the next 100–200 years, even for the Netherlands alone, building NEED might be better both technically and financially than scaling up existing protection measures.

Furthering the debate

Beyond the technical and financial considerations, initial reluctance to construct NEED might be based on possible impacts on

ocean dynamics, the environment, society, and politics. This warrants further debate.

We quantified the impact of NEED on ocean circulation using simulations with a version of the numerical ocean model NEMO that explicitly resolves tides.

Presently, a tidal Kelvin wave propagates anticlockwise around the North Sea basin, leading to large tidal amplitudes ($>1 \text{ m}$) and velocities ($>2 \text{ m s}^{-1}$). NEED would block exchange with the Atlantic and the tides in the North Sea, significantly reducing the velocities within the

Mega-enclosures such as NEED could be a solution to regional sea level rise in the (a) Irish and Mediterranean seas, (b) Red Sea, (c) Japanese Sea, and (d) Persian Gulf. *

enclosure, and affecting tidal amplitudes and thus the location of tidal energy dissipation and mixing.

As such, constructing NEED will have a large impact on the circulation and exchange of nutrients, sediment, and small marine life within the enclosure and possibly outside of the enclosure in the Atlantic Ocean and along the European Shelf. Even changes in atmospheric circulation and rain patterns cannot be excluded.

Forced migration is the most fraught of the possible adaptation measures, affecting millions of people and leading to loss of property and cultural heritage. These can be large burdens on the economic, social, and cultural values in the host area. Given this, protection is generally preferred. Unfortunately, even protection measures may lead to conflicts and can impact human rights. NEED, however, would significantly reduce the total length of required protection measures and place them in areas with a low population density or in the sea. In that regard, NEED could be a preferred solution.

While SLR is a slow but unstoppable process, an immediate response is required to reduce its negative social, economic, political, and cultural impacts. Unfortunately, divergent views among policy-makers continues to delay the implementation of adaptation.

Without new policy, however, SLR will lead to unavoidable and irreversible loss of physical places, cultural heritage, and environmental and ecological systems. Therefore, the question is which adaptation measures we should start to implement immediately. We believe that a policy that has the least direct impact on people's daily lives, at reasonable costs, has the largest potential to be implemented with the required urgency to be effective. As NEED would be constructed mostly in the sea and may have financial advantages over individual protection measures, it could become a solution with which policy-makers spanning political parties, countries, and generations can concur. We are at the point where NEED represents a solution of the scale that is required to counter the threat we are facing.

The best solution, not only in Europe but in vulnerable areas around the world, will always be treatment of the cause: human-caused climate change. If, however, climate change is left unmitigated, only solutions as impactful as NEED, or worse, will remain. It is our hope that the mere suggestion of NEED as a solution may spark global-scale action to address long-term, climate change-related threats. We therefore advocate for immediate action to further intensify climate mitigation efforts so that global-mean SLR can be limited and there will be no need for NEED. ●●

≡ METADATA

BAMS: What would you like readers to learn from this article?

Sjoerd Groeskamp [Royal Netherlands Institute for Sea Research (NIOZ), and Utrecht University]: *That we must mitigate climate change now. If we don't, there will be no good solutions left to deal with the consequences. We showcase that NEED is one of the least-bad solutions, and yet it's something you really don't want. So let it be a wake-up call to mitigate climate change and avoid such dramatic solutions.*

BAMS: How did you become interested in the topic of this article?

SG: *I was living in Australia and thinking about moving back to the Netherlands, my home country. As it is mostly below sea level, and sea level is rising fast, I was wondering if this was a good idea. I started thinking about protecting the Dutch coast, looking at a map of Europe, and the idea soon came up. I started doing some initial calculations and realized it's not impossible. The rest is in the paper.*

BAMS: What surprised you the most about the work you document in this article?

SG: *That NEED is actually one of the most feasible solutions.*

BAMS: What was the biggest challenge you encountered while doing this work?

SG: *The idea is "out there," so making sure the message is well communicated in the paper was the biggest challenge. That is: NEED is one of the most viable solutions, but we don't want it! We can still avoid it if we act now to mitigate climate change.*

BAMS: How will you follow up?

SG: *Possibly some collaboration with engineers in the Netherlands to explore alternative ways of construction and protection that sprung from this idea, but are hopefully less negatively impactful.*