The Longship that could help save the planet

Tina Bru: (in the background) *I dag skal et nytt langskip sjøsettes. Regjeringen legger i dag frem en stortingsmelding hvor vi anbefaler å igangsette det norske prosjektet for fangst og lagring av CO_2. Vi har valgt å kalle det "Langskip".*
Vikingenes langskip var den ypperste av sin tids skipsteknologi og et resultat av innovasjon og hardt arbeid. Vårt langskip er også resultat av ny teknologi og hardt arbeid av industri og myndigheter. Dette er det største klimaprosjektet i norsk industri noensinne.

Nancy: (voice over) That's Tina Bru, the Norwegian Minister of Petroleum and Energy, in mid September.

Norway, she says, is about to launch a new project as advanced as Viking ships were in their day.

This project, called Longship, will take Norway on a long, demanding journey.

It will cost money, lots of money. In its own way, it could be as dangerous as the hidden reefs, strong currents and North Atlantic storms that Vikings faced in their day.

But if Longship succeeds, it could help save the world.

Nancy: Whether you've sweltered in last summer's heat, or watched in horror as forest fires burned up huge chunks of Australia, Siberia and North America, you know that climate change isn't just something our children are going to face.

It's here, now, and it's a huge problem.

So that Longship that Tina Bru is promoting?

It's a plan to use a technology called carbon capture and storage — often called CCS —to fight climate change. The Norwegian government has committed 17 billion Norwegian kroner to turn a carbon-belching cement factory into a climate best-of-class.

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Nancy: I'm Nancy Bazilchuk, and you're listening to *63 Degrees North*, an original podcast from NTNU, the Norwegian University of Science and Technology.

Today I'm going to tell you the story of what Norway has done to turn carbon capture and storage into a viable technology that can help slow global warming.

It wasn't always smooth sailing. It's been a big financial commitment on the part of what is basically a pretty small country. There was even an early effort to launch a CCS project that Norway's politicians described as the equivalent of the US "moon landing" — but it didn't work.

But in the end, Norwegian researchers have delivered plenty of solid science that can help society shift away from fossil fuels and help lay the groundwork for a cooler planet.

And it starts here.

AX: Sound of Sleiper gas being injected

Nancy: It's December 14, 1992, and Norway's giant state-owned petroleum company, Statoil, has gotten an early Christmas present. Its Sleipner West gas field has just been approved for production. But there's just one problem — and it's a big one. The gas contains too much carbon dioxide to sell on the market.

Engineers know how to get the CO2 out of the gas — a chemical scrubbing system that's been used since the 1930s will do that job — but then what?

What will they do with the CO2?

Carbon dioxide is a problem for the climate, we all know, but there's a second reason why Statoil was really interested in keeping their CO2 out of the atmosphere. As early as 1992, Norway had a carbon tax.

That meant if Statoil released the captured CO2 into the air, they'd have to pay the tax — at the time, roughly 1 million kroner a DAY.

So they decided to do something different. It was something that hadn't been done before.

Olav Bolland: *The special thing about Sleipner is that they put it in the ground*.

Nancy: The engineers decided to inject CO2 from the Sleipner gas field deep into a sandstone formation, a saltwater aquifer, about 800 meters below sea level.

Engineers used a chemical called an amine to suck the CO2 out of the natural gas, and then they pumped it right back down into the sandstone. That sound I played at the beginning of the podcast? That's the sound of the CO2 being injected into the sandstone far below. To inject the CO2 into the sandstone, the engineers have to compress it to a pressure that would be like squeezing 365 soccer balls into one. That's a lot of pressure!

Think of this as a kind of an oil well in reverse. The sandstone is full of small holes and pores, which allows the CO2 to move around in the rock. The sandstone has a shale cap that traps the CO2 inside the rock formation. And at this depth, the CO2 is a colorless liquid that looks like water but behaves more like olive oil — it's light enough so that it floats atop the seawater in the sandstone.

This was a big, pioneering decision — it was the first time it had ever been done anywhere in the world on a commercial scale.

And it's been running ever since. Today more than 20 million tons of CO2 have been stored under the sea since 1996 — which makes it the longest running carbon capture and storage project in the world. That has given researchers and companies tons of information. This early success has also made Norway willing to be at the forefront of showing that capturing and storing CO2 can work.

Philip Ringrose: *The great thing about projects in Norway like Sleipner, which have been running for 23 years, is the proof of the pudding. It has been working pretty much uninterrupted for 23 years, with one single well disposing of all that CO2. It is definitely a solvable problem, we can definitely do large scale CO2 storage.*

Nancy: Philip Ringrose is a geoscientist specialist at Equinor, which is the new name for Statoil, and is also Norway's only professor of CO2 storage, at NTNU. He's also involved in the storage part of the new Longship project that the Norwegian government has endorsed.

Nancy: But with such a big price tag for the Longship project, you might wonder why we can't just cut carbon emissions by shifting over to windmills and electric cars?

Mona Mølvik: We need to reduce our CO2 emissions, and we do that with renewable energy, energy efficiency, but still when we have done all we can, we are stuck with Co2 emissions which need CCS.

Nancy: That's Mona Mølnvik, director of the Norwegian CCS Research Centre, and a project manager at SINTEF, an independent research institute that works closely with NTNU. The Intergovernmental Panel on Climate Change has made it very clear that if the world is going

to have a prayer of meeting its climate goals, we'll have to use every technique we can— including CCS.

Nancy: But every new fossil fuel power plant *isn't* fitted with a carbon capture technology — yet. Why aren't we doing everything we can to avoid dangerous global warming?

Olav Bolland: That is some of the challenge with power plants, that you have to remove fairly small amounts or small fractions of CO2, it's a lot of CO2 but small fractions. So it makes CO2 capture significantly more costly in a power plant compared to a natural gas purification plant.

Nancy: Olav Bolland is dean of NTNU's Faculty of Engineering and has been involved in carbon capture and storage research since 1989. He's also just co-authored a new book called *Carbon Dioxide Emission Management in Power Generation*.

Nancy: The natural gas purification plant that Bolland is talking about — that's Sleipner. The power plant — that's a place called Mongstad, where Norway's moon landing crash landed. We'll hear more about that in a minute. But bottom line:

Olav: *The increased cost is what makes it difficult.*

Nancy: Norway has first-hand knowledge of just how expensive commercializing carbon capture and storage can be. The "Longship" project isn't the first time the government has tried to commercialize CO2 capture and storage on a large scale.

AX: Jens Stoltenberg 2007 New Year's Speech *"Da president Kennedy sa at amerikanerne skulle lande på månen innen 10 år hadde ikke amerikanerne vært ute i verdensrommet. De kom til månen innen 10 år. De satte seg mål. Og de nådde målene. Vår visjon er at vi innen 7 år skal få på plass den teknologien som gjør det mulig å rense utslipp av klimagasser. Det blir et viktig gjennombrudd for å få ned utslippene i Norge, og når vi lykkes tror jeg verden vil følge etter.*

Nancy (voiceover): This is former Prime Minister Jens Stoltenberg giving what has come to be known as his "Moon Landing" speech in 2007. This is the "Moon Landing that wasn't".

Here he's saying that Norway had the will and the money to invest in technologies to cut CO2 emissions. Here's where the country could use its technological expertise from projects like Sleipner, to pave the way to the future. The new installation would be at a gas power plant and refinery in a place called Mongstad.

Olav Bolland: I think they all had good hopes that that would be the first major power plant with CO2 capture and there was a lot of willingness on the part of politicians in most parties, they wanted this to happen. I think the prime minister at the time, Jens Stoltenberg, said that this would be Norway's moon landing compared to the US moon landing in 1969. It is by no means a moon landing. It was nothing close to what happened in the US after JFK said we are going to the moon and it was completely different from what was needed for making a power plant with CO2 capture.

Nancy: In the end, the Norwegian government invested nearly 1 billion US in trying to establish carbon capture and storage at that plant. In September, 2013, with costs spiraling out of control, the government pulled the plug.

Nancy: But Bolland said the reasons it didn't work had less to do with the technology and more about the actual power plant that they were trying to convert.

Bolland: This was an existing power plant that is very tightly integrated with the refinery at Mongstad, that is a refinery that is running, so going in there and trying to do a CO2 capture plant, there were so much restrictions and requirements because of the refinery operation. It made many of the technical solutions more expensive and complicated than it could have been.When I look back at it now, Mongstad was a difficult case to make such a first plant. But wisely it ended up not being accepted by the Norwegian Storting, because it would have been wrong to spend all that money for one CO2 capture plant.

Nancy: With such a spectacular and expensive failure, you'd think that Norway might be willing to give up. But Norway takes climate change seriously, and Norwegian Prime Minister Erna Solberg says that the Longship project is the right thing to do. She wants to be able to keep Norway's promise to cut its CO2 emissions by at least 50 percent by 2030. But there's an economic motive too: she also sees a potential new market for Norway's offshore engineering expertise — and for its storage capacity.

Nancy: So here's what the Longship project involves.

Philip: *The current plan, which looks really good, is to find the most cost effective ways to capture CO2 and the lowest hanging fruit, and it turned out that was a cement plant and a waste recycling plant. And then use those to kick start the process, bring that captured CO2 to port in Oslo, and ship it round to the most suitable storage site, which is west of Bergen.*

Nancy: The Norwegian government has said it will provide nearly 17 billion kroner — that's 1.8 billion US dollars — to support CO2 capture and storage at the cement plant. Cement is the glue in concrete, which is one of the essential building components in nearly every kind of structure you can think of — from bridges to

buildings. But you can't make cement without major CO2 emissions — as much as 8 percent of all of the world's CO2 emissions come from cement production. A second part of the plan calls for supporting CO2 capture at a waste recycling plant in Oslo, but only if the project can find other financing, too.

But here's something that's really interesting. Norway is a petroleum producing country. Something like 36 per cent of its income from exports comes from oil. Nevertheless, politicians decided not to make this huge investment in CCS in its oil and gas industry. Philip Ringrose again.

Philip: One exciting thing about the current Norwegian project — it's not focused on decarbonizing oil and gas, it's focused on decarbonizing industry from land. Norway has taken a bold step, and said well the really key challenge is decarbonising industry, cement, steel, waste recycling. If we can pioneer that in Norway we can see that rolling out around the rest of the world.

Nancy: The first two steps of this process are to pull the CO2 out of the emissions, and transport it to a collection area. Then you have to get it out to where you're going to store it. In this case, the plan calls for ….

Philip: …..*a single pipe to a single wellhead offshore to dispose of that Co2.*

Nancy: A wellhead, that's geology speak for the top of a well. So, some of you may be thinking, ahha! Norway is going to reuse old oil wells to store CO2! Brilliant! The ultimate in recycling!!! But… no. It turns out that CO2 is slightly acidic, so the wells have to be able to tolerate that.

Philip: You could to some extent use old wells but old wells do have the problem that they are old, they could be corroded, they've been around for 20 years perhaps, so our vision is very much, use the old knowledge from the old wells and they are what we use to characterize our geological formations, but primarily go for new wells, which will be the cheapest in class, cost effective new wells that will dispose of CO2. And there is one slight difference with CO2 injection wells. They need to be corrosion resistant, because CO2 reacting with water is a very weak acid. So when you are operating a CO2 injection well you need slightly better elements, the steels, the rubber membranes, than you might have in a conventional gas well.

Nancy: So you can't save money by reusing old oil wells. But you can help save the planet — even if it is expensive on the face of it.

Philip: It is quite an expensive project in total investments to get it going, but it is the cheapest of all those elements. We have picked the cheapest capture, the cheapest route to transport it and the cheapest way to dispose of it underground. So it should be a good project to kick start CCS. And once you get the first project, hopefully you can build on that and get economies of scale, so the whole process becomes cost effective. But also have the ability to scale up.

Nancy: And scaling up shouldn't be a problem, at least when it comes to storage. Experts like Ringrose have looked at how much storage capacity there is out there for CO2.

Philip: We reviewed all of the global offshore basin data, the Gulf of Mexico and the North Sea were the main focus but we looked at the entire planet, and our question we were trying to address was "What actually is the storage capacity of our world globally?" And we found out it's huge. We have plenty of room to store CO2.

Nancy: By now you might be asking yourself: is it actually a good idea to pump CO2 into undersea rock formations? Is it safe? Philip Ringrose.

Philip: The law has certain requirements: you must monitor, and the two things the law requires are that you must show that your monitoring goes according to plan. We call that conformance. And then the other is that you must show there is no risk of leakage. So the monitoring activities, which usually include geophysical imaging, listening to micro earthquakes, recording the pressure continuously in a well. These monitoring methods are designed to ensure all the stakeholders in the project which might be government officials, but very often members of the public, just assure them that this project is going to plan.

And certainly I think one of the requirements for CO2 projects in the next decades is they are going to have to be quite open about this monitoring data. They are going to have to show people time and time again this site is going ok.

Nancy: Remember the Sleipner gas field, the first place in the world where CO2 was injected under the sea? That long history from Sleipner has really helped geologists understand what's going on over time as the CO2 is injected.

Philip: We have been sharing time lapse seismic data with research institutes globally for decades now, so that any researcher can see the data and say yup, yup,looks good, there's the CO2, I can see it!

Nancy: Here we need a little translation: Time Lapse seismic data??

Philip: It's a bit like… it's very analogous to imaging a baby in the womb, you're using a sonic sound wave into the Earth to look at the changes in response. When you do seismic imaging in the Earth, you send these soundwaves down and you can record the reflected layers in the Earth, and we use that for mapping.
But the great thing about CO2 is when you inject CO2, it changes those reflection properties in the Earth, so then when you shoot a second survey, a time lapse survey, you see the change in reflectivity as where the CO2 is. Obviously it's a remote method so you can't see every molecule of CO2 everywhere, but you can see all the thick layers of CO2 with seismic imaging.

Nancy: So not only do we have the science to show that this can be done safely, but the project will be closely monitored, with the information shared openly so we know what's going on.

Nancy: That's all good, because here's another selling point that Erna Solberg has used to build support for the project. She points out that capturing CO2 from both the cement plant and the waste recycling plant will fill only 40 per cent of the storage capacity for this one well, which Ringrose and his colleagues say has the capacity to store 100 million tonnes of CO2. She's hoping that the EU could become a customer..

Nancy: Cost is going to be an issue. But every technology is expensive when it is first rolled out, full scale. And then there's the question of getting what you pay for. Philip Ringrose again.

Philip: Many researchers have been working on all aspects of the capture transport and storage chain for decades, so there's no doubt it's a mature technology. So the real question is, do societies want to deploy that technology. But you're talking about paying a reasonable amount of money to get rid of gases you don't want to throw into the atmosphere.
It is a question of relative values, in Norway and Sweden, and other countries around the world, there is a carbon price already in place, our societies work fine with our carbon price. All you're saying is it's not permitted to throw CO2 into the atmosphere or if you do you have to pay. It is very much analogous to its not permitted to throw garbage into the river that's polluting our drinking water supply, and if you did as an industry, you'd be fined a lot of money. So taxing CO2 emissions to the atmosphere is a practical way of making sure we change our behaviours, and as soon as we have a society with a tax or cost to emitting CO2 to the atmosphere, these other industries will start happening automatically. We will find ways to do it, cost effectively.

Nancy: All of this is good news, because when the Intergovernmental Panel on Climate Change looked at how much CO2 we'll need to remove from the atmosphere to keep global

temperature increases to 1.5 degrees C, they calculated humanity will have to capture and store between 100 to 1000 gigatonnes of CO2 this century. Some people have voiced concerns that CCS will act like a crutch for companies that don't want to stop using fossil fuels. But remember, just by choosing to invest in CCS for a cement plant, Norway is acknowledging the 800 pound gorilla in the room — that we have to transition away from fossil fuels as soon as we can.

By the way, a gigaton, if you're wondering, is one BILLION tons. A one with nine zeros after it. And 1000 gigatonnes is a one with TWELVE zeros.
Nancy: Some people have voiced concerns that CO2 storage will act like a crutch for companies that don't want to stop using fossil fuels. But remember just by choosing to invest in CCS for a cement plant, Norway is acknowledging the 800 pound gorilla in the room, that we have to transition away from fossil fuels as soon as we can.

Philip: We've always argued that carbon capture and storage is a transition to a long term carbon free future.

Nancy: Nevertheless, there's no way we can put ALL of our unwanted CO2 under the sea. We'll need lots of other technologies to store carbon, like planting more trees and finding ways to get the soil to absorb more carbon.

But because of Norway's history and experience with Sleipner and other storage projects, the general consensus is that the place where the country can be of the most help is with storing CO2 under the sea. Geologists like Philip Ringrose and engineers like Olav Bolland and Mona Mølvik have demonstrated we CAN store it. But paying for it is part of the reason it hasn't happened yet on a large scale. That's where governments worldwide will have to act.

Philip: You know, there is this continual discussion about carbon capture, who is going to pay for it, why would you do something which isn't going to make you any money.
It might at first seem quite an expensive thing to do, but when you scale it up to a global or regional activity, it's actually a very cost effective thing to do.

Nancy: The Paris Agreement was one step towards action. Individual nations are also making pledges to cut emissions as early as 2030 or 2050. Countries are building more and more renewable energy projects. They're pushing to move personal transportation away from fossil fuels to electric cars. Look at GM in the US: they said that all the new cars they sell by 2035 will be electric cars. Many developed countries have programs to increase energy efficiencies in homes and commercial buildings. But some things we do, like make cement, just can't be done without CO2 emissions — at least not yet.

Philip: *When it comes to the hard questions, what am I going to do about heavy industry, about shipping— a lot of industrial processes that you cannot decarbonize fully without carbon capture, then you are going to have all this captured CO2 and you are going to want to do something with it.*

Nancy: And more and more there's a real cost to *not* dealing with CO2 — both for the planet and for the companies that want to sell their products. Regulators and consumers are realizing that emitting CO2 to the atmosphere has its own costs, and the pressure is on to act. Mona Mølnvik from the Norwegian CCS Centre.

Mona M.: We see the EU green deal, CO2 Border tax discussion, so many issues coming into play now. You can't ignore your CO2 emissions because you might not have a market for your products in the future.

Nancy: And engineers like Mona Mølnvik are also thinking about future ways of powering society that include carbon capture and storage as an integrated part of generating energy.

Mona: We will certainly see large scale hydrogen production with CCS, and this is a big main player which we will see in the coming years, we will see it in Norway, we will see it in Europe and we will see it around the world.

Nancy: Hydrogen as an energy source. If it's produced using natural gas and if the carbon is captured and stored during the process, it can be a clean, climate friendly source of energy.

Mona: Natural gas is mostly methane, and methane is one carbon and four hydrogen, you want to take out the carbon molecules, and keep the hydrogen molecules, and sell that as a carbon free fuel. Hydrogen produced from natural gas with CCS is a very important player together with hydrogen produced from renewable electricity because it can provide a lot more in a shorter time, so it is a solution for the energy transition.

Nancy: It may sound far-fetched, but this is not the first time that Norway has built an entire industry from scratch.

Mona: If we go back to the North Sea, 50 years ago or a little more than 50 years ago, there was almost nothing out there, and now it is a world of offshore technology.

You can imagine the same things going on for CCS.

Nancy: The message is clear: the climate science is there, and the technological know-how is ready, too. It's just a matter of getting politicians to see that our climate is worth the investment it will take to make CCS a reality. And in Norway, they seem to have..

Nancy: I'm Nancy Bazilchuk, and you've been listening to 63 Degrees North, an original podcast from NTNU, the Norwegian University of Science and Technology. If you've enjoyed today's show, we hope you'll let your friends know and leave us a rating on your podcast app. Editorial help and sound design by Randi Lillealtern from Historiebruket. Thanks for listening.